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THE
FITTING AND ERECTING OF ENGINES

By

C. LESLIE BROWNE

MANCHESTER
EMMOTT & CO., LIMITED
65 KING STREET
LONDON: 20 BEDFORD STREET, W.C.
1914
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D. VAN NOSTRAND COMPANY
NEW YORK

Published April 1913
Reprinted March 1914

186307
JUN 30 1914
THB
.B813

6950717

PREFACE

THE contents of this book, which appeared originally as a series of articles in the *Mechanical World*, have been written with the object of assisting young engineers in their practical work.

While the study of technical literature can never form a complete substitute for practical experience, it offers considerable assistance to the student of engineering, particularly if the *raison d'être* of the various practices is explained. With the oral instruction obtained in the workshop, this is usually omitted: hence the somewhat full explanation here given of the why and wherefore of the different processes may render the instruction more acceptable to the engineering student with an inquiring mind. At the same time, the author has been at no pains to avoid the atmosphere of the workshop, which is distinctly beneficial as an educational factor.

C. L. B.

STOCKPORT, *April* 1913.

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THE
FITTING AND ERECTING OF ENGINES

CHAPTER I

MODERN CONDITIONS

THE revolution that has been effected in the machine shop in recent years by the introduction of modern self-hardening steel, and by other causes, has been accompanied by changes in the fitting shop which, while not attracting so much attention, have perhaps been equally important.

The progress made during the last few years has practically sounded the death-knell of the old-time fitter so far as the manufacture of engines in modern works is concerned. The work that now comes round from the machine shop leaves much less for the fitter to do, and what work he has to do must be more accurately finished. The underlying idea has been to replace a human being by a machine wherever it is in any way possible. Thus, fitters do less and less fitting, their work gradually tending to become merely that of assembling the various parts. The writer does not wish to be understood to assert that really accurate work in engine building was unknown until recently, but it may be stated without fear of contradiction that it is only in very recent years that accuracy within small predetermined limits has been adopted as an aid towards cheap production.

First-rate workmanship has a high commercial value in a steam engine. Good design is, of course, necessary to a successful firm, but it presents no difficulties of any note, as engines built by the leading firms are running in this country, and the beautifully-designed engines built by Italian, German and Swiss firms may be seen at work in England. Good material is also essential, but with the exception of copper and one or two other alloys, good material comes out very nearly as cheap as bad material. It pays in the foundry to use good iron in order to get good, clean, sound castings that will machine up without difficulty, and these are the sort of castings required to make good engines.

On the other hand, to produce really good workmanship at a reasonable labour cost means getting together a crowd of intelligent workmen, setting up a definite standard and seeing that it is rigidly adhered to. This means some hard uphill work on certain predetermined lines.

Without good workmanship, good design and material are nullified. Repeat orders come from those customers who find that the engines which they have bought give no trouble, but run economically year in and year out with the minimum cost for maintenance and repairs. This qualification can only be obtained with engines that are properly fitted and erected.

In order to secure the best results, harmonious relations are essential between the respective heads of the machine and fitting departments. It is when the machined parts come to be fitted together that the faults in machining are discovered, and in looking into such faults it often happens that they may be traced back to some error in the machine tool which performed the operation under discussion. Thus, in such cases the cause of the fault may be removed and its repetition prevented by the friendly co-operation of the heads of the departments in question. Higher cutting speeds and coarser feeds mean greater stresses in the stock undergoing the operation of machining, and this generally means that it must be more rigidly held. Thus many peculiar distortions in large machined castings can be traced to the warping produced in the castings by their being bolted down with insufficient care upon the machine bed or table. This is the kind of thing that has to be detected and put right in the fitting shop, and the chances of its recurrence can be much reduced by submitting the error and its probable cause to the machine-shop manager.

Feed and speed hustling has also given the " corduroy finish " a permanent place on our machined castings, and while this finish is objectionable in the fitting shop for several reasons, it is not entirely without its compensations. The works manager of a large firm used rather to encourage the " corduroy finish " on machined faces to which brackets requiring to be " thrown " were to be bolted, the reason alleged being that this surface formed miniature " chipping strips," and when scraping or filing up the facing his men had to remove only one-half of the metal that would have been necessary had the machine finish been a good one.

There is, however, no doubt that a little more care in the machine shop would considerably diminish the amount of work in the fitting and erecting shops. On the other hand, while extra work in the machine shop would in many cases reduce certain fitting costs, it is quite possible that the degree of saving effected in the erecting shop might not warrant the additional expenditure in machining. This is a case in point where the respective heads of the departments concerned can by friendly consultation so arrange the work in each department that the total cost is the lowest possible irrespective of where the most work is done.

There was a time when the workman followed his own work through the shops. Fitting and turning were one and the same trade, and there are still fitters to be met with who can do their own turning, and can, if necessity arise, work a planer or any other machine in the shop. Owing to the progress of specialization the one trade became divided into two. There is again a tendency nowadays to encourage the fitter to make use of small power-driven tackle, such as small electrically-driven portable tools, including drills, screwdrivers, grinders, etc. Such tools can often be picked up by the erector and the job finished in less than one-quarter of the time that would be required without them. But although the work of a modern fitter has become more specialized there is quite as much skill required, though of a different kind. A workman trained in a modern shop would be a little puzzled if he were told to chip and file up a big lathe bed rough from the foundry; but when machined he would probably scrape it up to a better surface than was obtained with the average lathe bed twenty years ago.

It is a common saying that " a good workman never blames his tools." There is a certain amount of truth in this saying, although it is, on the face of it, evident that its author never worked in an engineering shop. It is, however, equally true that a good workman never uses poor tools. It will always be found that the successful workman has collected in his tool-box a set of tools upon which he can rely in emergencies, and in which he takes some little pride. Not only does the steel in workshop tools vary greatly in quality, but very different results are often obtained in tempering cutting tools even when tempered by the same smith. When a chisel that seldom requires regrinding comes the way of the fitter, he should always endeavour to keep it in his possession and treat it with care. The same thing applies in a greater degree to scrapers. No matter how carefully some scrapers are tempered, they fail to hold their edge for any length of time. A repair job was being rushed through a shop in the shape of a large rope pulley. When the time came to stake the pulley on to its shaft, one workman was put on to each key. It was very noticeable that one of the workmen kept well ahead of the others without apparently exerting himself, while the remainder were endeavouring, by regrinding their scrapers and repeatedly rubbing them on the oilstone, to keep the pace. When the job was finished the writer went over to examine the scraper which was used by the fitter who had finished first so easily, and found it to be composed of an exceptionally fine piece of steel. Inquiries were made in the office, and more of this quality of steel got forward; but the point on which it is desired to lay stress is that this workman has been promoted to the position of leading hand with a rise in wages of 4s. a week on the strength of the rapidity and excellence of his workmanship. This was almost entirely due to the care with which he selected and preserved his tools.

It should always be made a rule to grind and sharpen tools on the completion of a job. Ability on the part of a fitter to start immediately on a hurried job when required is in itself an excellent indication of smartness, whereas a workman who has to fettle up and sharpen his tools, and thus delay an urgent job, is likely to create an unfavourable impression upon his official superior.

Having collected a good set of tools, it is necessary to take such ordinary precautions as suggest themselves in order to keep them. It is not desirable to leave good tools lying about upon the bench. All tools that can be possibly put away should be returned to their owner's box or drawer at meal hours or when leaving for the night. Whatever receptacle is used for the above purpose should be securely fastened, as there will always be found in every shop one or two of those free lances whose skill in judicious annexation has been developed by long practice. There is also the inveterate borrower to be guarded against—he who always prefers to use the good tools of others rather than his own, which are invariably few in number and feeble in quality and condition. Such individuals should be gently but firmly discouraged if the fitter hopes to keep a good kit of tools together.

Another point, on which the erector has often something to say, is the choice of a mate. Fitters' labourers are generally classed as unskilled, whereas a good labourer is quite highly skilled in the requirements of an engineering works. A bright, intelligent, handy man, who can anticipate an erector's wants, is worth a great deal as a mate, and will help to increase his daily output without unduly straining himself. It is a matter of common knowledge to practical men that there are moments when it is impossible for an erector to find his labourer a job, and yet, as his services will shortly be again required, it would be impracticable to send him away in search of another job. At the same time, as it is not always possible to explain to a passing official the exact state of affairs, and as it is not advisable that he should receive a wrong impression, some little diplomacy is required. An experienced and intelligent labourer will attend to this kind of business, and can always be relied upon to maintain a correct attitude under such circumstances. On the other hand, a labourer who has a too-highly-developed talent as a raconteur will make a pleasing and cheerful companion, but will not tend to advance the erector in his career in the works.

As the working hours spent in a workshop are not usually the most pleasant in a workman's life, he exhibits a natural tendency to strike the mean line of conduct calculated both to " fetch Saturday " and at the same time to keep his job. It is his endeavour to make the working hours pass as rapidly and pleasantly as possible. But it is true beyond all dispute that close concentration on a job makes the shortest day, and an intelligent interest in the work makes the hours pass most pleasantly.

The erector should follow out the theories that underlie the various designs of engine parts that pass through his hands, and endeavour to trace the connection between the shapes and proportions of the working parts and the stresses to which they will be subjected when under working conditions. An engine can be well erected only by a workman who fully understands the functions which the various details have to perform. The fitter, when fitting in a key, will be guided as to the time he will spend in bedding it into place by an intelligent anticipation of the shocks to which it will be subjected. Even the simple operation of tightening up a bolt is governed by a knowledge of the work which that bolt will have to do. The same argument applies to bearings. Crosshead-pin brasses do not require the same treatment as is necessary at the crankpin end of the connecting-rod.

Workshop conditions in modern engineering works are vastly better than in the old-fashioned shops. With regard to light, warmth, and in many other ways, the workman's comfort is now considered to the advantage both of the men and of the employer.

In many shops building large engines it is the practice to send out, to erect the engines on the job, the man who has had charge of their erection in the shops. This is for many reasons an excellent practice, one of them being that the erector is not likely to attempt to gain credit for hustling the job through the shop, to the detriment of its behaviour when erected and started up outside. Under these conditions the erector will not unduly hurry over the lining-up of an engine, or scamp the work on the bearings, when he knows that he will be the individual to face any consequent hot bearings later on. But even in works where an independent outside staff is kept, the fitter should, although for a different reason, exercise equally as much care as though he were going to run the engine himself. One consideration should be that it will be impossible for him to cover up outside any shortcomings in his work in the shop, and also because it is a well-known axiom of an outside staff that the next best thing to erecting and running an engine with dispatch and success is to send in to headquarters serious complaints as to the state in which the engines are sent out from the works.

CHAPTER II

MAINLY ON BEARINGS

PERHAPS the easiest engine to fit and erect is that of the quick-revolution type. The class of engine now made is really a survival of the fittest. Nearly all the freak "high-speed" engines that were put on the market from time to time up to about five years ago have ceased to be manufactured, and their wood patterns have gone to make steam under the boilers. Some of these monstrosities—of which anyone who has been connected with steam engineering for the last ten or fifteen years will remember two or three examples—required exceptional skill in their erection and running. It was certainly a liberal education to any erector who worked upon them, as the most careful fitting was required to get them to run at all, and such was their inaccessibility that an expert contortionist was required to make properly some of the necessary adjustments, quite a large percentage of the nuts having to be tightened up with a hammer and long chisel.

The quick-revolution engine of to-day has been shorn of all but its vital parts. It has been designed not only to run continuously, practically without attention, but the machine work has been simplified and the amount of fitting reduced to the minimum. Such fitting, however, as there is on the job must be carried out on rigidly high-class lines. Workmanship which would not interfere with the usual style of running of a low-speed horizontal engine would be absolutely fatal with the class of engine under consideration. Hence it is proposed to follow in some detail the fitting up of one of these engines.

The class of engine to be dealt with is the double-acting quick-revolution type with forced lubrication. Except for special purposes, the single-acting quick-revolution type of engine is gradually ceasing to be manufactured. These engines are all usually referred to as " high-speed " steam engines. The double-acting varieties differ somewhat in details of design, but the following remarks apply to nearly all the leading standard designs on the market.

After the engine bedplate comes through from the fettling shop, it should go to the pickling tank before coming into the machine shop. Not only is it an advantage to remove the scale from the casting in order to economize in machining, but the interior of the bedplate forms the crank-race, and when the engine is at work will hold the oil required for the lubrication of the working parts. A pure mineral oil manufactured from a good " crude " is extremely searching, and untold trouble has been caused, after several weeks' working, by the oil loosening scabs and scale which, at the time the engine was erected, appeared to form a homogeneous part of the casting. Such grit and dirt has got churned up into the oil and thence worked into the bearings.

From the pickling bath the engine goes to the marking-off table, where it is first tested to make sure that it will hold up to the dimensions of the drawing before any further work is done upon it. Having been found to be all right in this respect, the bedplate is marked off for machining. The top and bottom of the bed have to be planed and various faces machined. The holes also have to be drilled and tapped, among them being those for the studs necessary for holding down the main bearing caps. Of course all the marking-off cannot be done at one time, a certain amount of machining having to be finished before the marking-off for other operations can be carried out.

Great care must be exercised in fitting the main bearing studs, as the full stresses of the engine come upon them. The thread should be a good fit all the way down, and not come tight only at the root. Taps vary a little in size, and it is not uncommon to find one that has warped a little in hardening. In fact, the tap makers usually test the taps for truth after being dipped by placing them between centres and spinning them round by hand. Should they show any eccentricity to the eye, they are not sent forward to any customer who is known to be both vigilant and particular. Many of these taps, however, are to be found up and down the country, and the fitter will do well to be on his guard against them. Further, a blunt tap will make a larger hole than a tap that is sharp. Fortunately, high-class firms have ceased to screw studs for this purpose in ordinary screwing machines. They are generally turned out by turret lathes, and are in consequence more accurately finished. The holes, too, where tapped under the machine, are more true than if tapped by hand. Should an erector come across a main bearing stud that is slack in the tapped hole until it comes to the bottom, he should reject it.

After the main bearing caps are in position the job may then be bored out for the main bearing brasses and faced where required. The locating of the standard on the bedplate will be referred to later. The term " brasses " is still used in the workshop, in spite of the fact that the object referred to consists of a cast-iron shell lined with a white-metal alloy. The bottom brass is now generally made cylindrical in shape. Firstly, because it is a little cheaper in this form; secondly, because it is possible with a cylindrical brass to take the weight of the shaft, and by turning the brass round the latter get it out for inspection; whereas the square bottom brass necessitated the shaft being lifted clear before the brass could be removed. This brass has now to be bedded into its place in the bedplate, and as the boring tool has left a sharp edge on entering and leaving each pocket, this sharp edge must be carefully rounded in order to prevent it from fouling the radius left by the tool at the root of the end flanges of the brass. This having been accomplished, the brass must be thoroughly well bedded down into position. Not only is this necessary in order that the brass may be well held up to the shaft, but also to facilitate the conduction of heat away from the main bearing. This latter point has to be carefully watched in some open-type engines, and while it is not of such vital importance where forced lubrication is used, it is well worth bearing in mind.

Heat is generated in every working bearing, and the temperature rise in any particular bearing depends, among other things, upon the rate at which that heat can be removed by radiation and conduction. The rate of radiation depends, other things being the same, upon the extent of the radiating surfaces, and by careful design and fitting it can generally be arranged that the heat generated is rapidly conducted to the framework of the engine, and the large surface of the latter is then employed in the process of radiation. An engineer once packed up an engine bearing with thin cardboard, and the bearing, which had always run a little on the warm side, was smoking within an hour after starting up, and could not be got to run cool until the cardboard, which acted as an excellent non-conductor of heat, was removed. Quick-revolution engines always run with their bearings a little warm, the temperature generally reaching over 100° F. after the engine has been at work for some time. This is partly due to the natural heat of the bearings and the churning up of the oil, but chiefly to the heat of the cylinders being conducted through the cylinder distance-piece to the frame of the engine and thus to the bearings, and also to the heat of the piston rod. This latter effect is greater with small engines than with large ones.

In bedding in these brasses it will generally be found better to remove most of the metal that has to be got rid of from the back of the brass rather than from the recess in the bed. From the process of shaping the surfaces, the back of the brasses is more likely to be truly cylindrical than the bed in which it will lie, as the boring bar is more likely to spring than the brasses when chucked in the lathe. On the other hand, it is much easier to file the back of the brass. Thus, the usual practice is to remove, with a second cut file or scraper, any roughness of lumps in the bed where the brasses lie, and then let down the bottom brass into it. Further, the running of the molten white metal into the cast-iron shell generally has the effect of opening it out slightly. The expansion of the inner surface due to the heat causes this distortion, and the shell in cooling does not quite recover its former shape. The result of this is that the brass when put into its seating often bears on its sides and not on the crown, the former having to be eased away.

To run white metal into a bearing in a proper manner requires a good deal of skill and experience. This job should not be done in the foundry, as sand and grit are best kept away from an engine bearing. The cast-iron shell should always be tinned before the metal is poured, otherwise it is improbable that there will be a proper union between the two metals, which is of the first importance if the best running results are to be obtained. It is best to heat the shell a little before the metal is poured, but it is impossible to give the best temperature, as this depends to some extent upon the melting point of the alloy, which varies a little in accordance with the metals which go to make up the alloy. The more expensive alloys usually have a lower melting point than that obtained with the cheaper mixtures, owing to the higher percentage of tin employed. The men on the job soon learn what are the best temperatures to work at, being also guided by the maker's instruction, especially where the same brand is constantly used. They usually employ a pyrometric method for arriving at the right temperature of the shell, which is not to be found in the ordinary text-books, but appears to give sufficiently accurate results. The method referred to is that used by the old-fashioned laundry-maid to ascertain the temperature of her flat-iron. The top half of the brass will also require to be carefully bedded into the cap, using red-lead or other marking, as with the bottom brass, in order that a thoroughly good job may be obtained. The crankshaft may then be brought along to be bedded into the bearings. This is a job requiring both skill and care, as a first-class bed is required to enable the engine to run continuously at high speeds without appreciable wear after years of work.

CHAPTER III

ENGINE MAIN BEARINGS

BEFORE lowering the shaft into place it is advisable to take each brass in turn out of the bed and try it on the shaft to make sure that it will come down on the crown. It will usually be found that the brass bears hard upon its edges, and while at this stage it is important that the bed should be a good one, it must be made certain that the crown comes hard on to the shaft. If this were not done it is possible that the shaft when being lowered would wedge itself into the brass and thus possibly cause some damage. The brasses may then be returned to the bed and the shaft rubbed very thinly with marking and lowered into the brasses. After the shaft has been revolved to show where the white metal is bearing hard on the shaft, the latter is lifted out and the brasses scraped up wherever the marking shows. Scrapers for use on white metal are ground to a much more acute angle than for brass, and to get good work at a rapid rate the cutting edges should be most carefully finished on the oil-stone. The scrapers used for this job are three in number—viz., the round nose, the half-round with one handle, and the half-round scraper with one handle at each end. The round-nosed scraper is only used where there is a good deal of metal to come off. The total cutting area is small, and consequently with a given weight applied the pressure per lineal inch of the cutting edge is high, and the scraper will take heavy cuts, leaving a comparatively deep furrow at each stroke. This scraper is obviously not the tool to be used for finishing. The half-round scraper with the single handle is often formed from a half-round file bent back at a large radius and ground on the flat side and on both edges. The length of cutting edge in contact with the metal depends obviously upon the curvature of the scraper. It is noticeable that this curvature in the majority of scrapers is too great for fine work of this class, resulting in a series of grooves in the metal being left wherever a cut has been taken. With a soft bearing metal a wider cut can be taken than in the case of brass, and yet it is a common thing to see the same curvature in scrapers used for both classes of work.

In order to be able to use one single-handled scraper at various stages of finish on a bearing, it is necessary slightly to increase the curvature of the scraper, or, in other words, to decrease its radius of curvature from the handle to the point. This enables the width and depth of the cut to be varied by working at different points along the cutting edge. Provided that the curvature is only slight compared with what is often seen in engineering workshops, and increases quite uniformly in curvature towards the point, and provided also that the cutting edge is kept in first-class condition and is of high-grade steel, the fitter will have a tool in his hands that will enable him to turn out first-class work in the minimum of time. The third class of scraper referred to is that with a handle at both ends. The cutting edge of this scraper should be very nearly a straight line, the curvature being only just sufficient to enable the cut to be taken at a definite spot. As this scraper, owing to its small curvature, takes a wide cut, considerable pressure is required to remove any great weight of metal. Hence the two handles, the scraper being drawn towards the workman on the cutting stroke. This tool is useful for removing the high places left after roughing-out with the other scrapers.

When the finishing stages of the job are reached the marking should be rubbed on the shaft so thinly that it is only just visible, since by turning the shaft round two or three times dark patches will always show on the hard spots. Of course, if the marking be put on in sufficiently large quantities, the shaft will always appear to be bearing well all over the brasses, provided that it will enter the latter. The not uncommon practice of increasing the thickness of the marking on the shaft when the fitter thinks that he has spent as much time as is wise on the job should be discouraged when working on high-speed engines. An erector who has been accustomed to working on open-type low-speed engines only will, when working on high-speed engines, probably want to ease away a lot of metal from the sides of the brass. The chief object of this practice is to provide for a wedge-shaped film of oil, which will insinuate itself under the crankshaft and thus be carried round to the under side of the journal. Anyone familiar with the practice in marine-engine circles will have come across a number of brasses in which the metal is eased away on one side only of the brass, and that on the side on which it will be carried round under the journal by the action of the revolving shaft when the engine is running ahead. In other cases it will be found that the brass is allowed to touch the sides of the journal for a short distance at each end, the remainder of the sides being eased out as above. The object of this course is obviously to prevent too much oil escaping out of the ends of the brass. Another reason given for the adoption of the practice under consideration is that there is a danger of the brass closing in at the sides and nipping the journal should any undue heating occur. An extreme case where there is a danger of this occurring will be found in such an instance as a crankpin with a heavy solid-end type connecting-rod and heavy gunmetal brasses. In the event of the heat of the crankpin coming up quickly and causing it to expand, the heat will also be communicated to the brass. The rod meanwhile being kept cooler by its rapid movement through the air, the brass is liable to expand inwards, its coefficient of expansion being much greater than that of the steel. If the brass were a very tight fit in the rod, the cooler portion of the latter would naturally prevent the brass from expanding outwards, and these causes would tend to take up very rapidly the normal clearance between the pin and the brass. If this clearance were not sufficient the bearing would, of course, seize up. Now, in the case of the type of engine previously under consideration, the conditions are very different. In the first place it is necessary to decrease the clearance round the journals in order to keep up the pressure of the oil by preventing its free escape, and the question is: To what extent can this be done without incurring any danger? It is also desirable to get as large a bearing as possible on the brass in order to diminish the pressure per square inch, and this means letting it bed well round the shaft. Supposing that it were possible for the crankshaft to heat up to such a temperature that the white metal would begin to drag, and that the brasses remained quite cool and their diameter inside did not increase, a clearance at each side of a 6in. shaft of about 0.006in. would prevent the brasses from gripping the shaft in the manner referred to. Further, although the coefficient of expansion of the white metal is certainly greater than that of iron, the thickness of the white metal bearing is so small as to reduce the total amount of expansion to an infinitesimal figure. Where forced lubrication is employed, the quantity of oil passing through the bearings tends to keep all parts in their neighbourhood at a uniform temperature. Thus in high-speed engines the danger referred to is non-existent, and with ordinary care and precaution a hot bearing is practically impossible. It is, of course, unnecessary to state that in a vertical engine there is but little pressure normal to the surface of the brass at its edges level with the centre of the shaft, and absolutely no advantage is gained, beyond that of retaining the oil, by having the brass and journal in actual contact at this point. Thus, in accordance with the best high-speed engine practice, the side clearance should not exceed a few thousandths of an inch, and a thoroughly good bed be obtained round three-quarters of the bottom brass, the same, of course, applying to the top brass.

CHAPTER IV

ADJUSTMENT OF BEARINGS AND FITTING OF ECCENTRICS

THE subject of the adjustment of bearings has been the cause of learned disquisitions ever since steam engines were first made, the difference in the views enunciated being probably due to the differences in design and the various conditions of running. It is not an uncommon thing to be told in connection with certain bearings that the nuts of the main bearing bolts must not be pulled up too tightly for fear that the journal will run hot. Such a condition of things could not be allowed in a high-speed engine. To put the matter briefly, the main bearing studs, or bolts, as the case may be, should be pulled up until the tensional stress in them at least exceeds any normal stress which could come upon them while the engine is working. If there were no initial stress in these studs, they would stretch at every up-stroke of the engine, and the main bearing cap would lift by the same amount. In order that the additional stretch of the studs may be eliminated during the up-stroke of the engine, it is necessary that the details of the bearing be designed with this point in view. In the first place, a very rigid design of cap is required in order that it may not spring in the centre under working stress, it being in the condition of a beam supported at both ends and loaded between the points of support. Further, the metal in it should be so arranged that it will not be sprung when pulled down by its bolts. When the cap is pulled hard down the tension on the studs is balanced by the compressive stresses at the joints between the upper and lower halves of the bearing. The upward pull of the steam tends to draw the metal surfaces apart at the joint, and an extreme case may be imagined in which very stiff springs are inserted in the joint. In this case, in spite of the initial stress in the stud, the cap would lift under the steam pressure on the piston, because the springs would continue to press upward as much as the studs would pull down, their elasticity allowing them to follow up the stretch of the studs under load. The other extreme would be an imaginative case in which the metal at the joints and that taking the compressive stresses elsewhere were incompressible. If this were so, provided that the initial nip down stress upon the studs is greater than the upward pull of the steam, there would be no upward movement of the cap, and no increased tension on the studs when the engine was working. The pressure at the joints of the brass would, however, be decreased. In order to approach as nearly as possible to these latter ideal conditions it is an advantage to have the studs long so as to increase their total elongation under a given stress, and to have the section of the metal cap in a plane at right angles to the direction of the applied load as large as possible. In order to let the top half of the bearing into the corresponding pocket in the bedplate, the surface which comes into actual contact with the bottom half of the bearing is generally of comparatively narrow width at each side of the shaft. This will not materially oppose the conditions stated above as desirable, provided that the projection of these faces beyond the main body of the cap is very small compared with the length of the studs or bolts. This matter has been well taken care of in the designs of high-speed engines built by the leading firms, and the erector, bearing in mind the theory embodied in these designs, will be able to eliminate all knock from his engine as far as close attention to the main bearings can go.

Another point is: What should be the clearance left between the top of the shaft and the upper half of the bearing when the nuts are pulled well home? This, again, is a subject on which various opinions have been given, and tables have been published giving the necessary clearance round the shaft. It will usually be found in such tables that the clearances recommended vary in proportion to the square root of the diameter of the shaft. Now, if the clearance is to allow for any expansion of the shaft due to heating, it should obviously vary directly as the diameter. If, on the other hand, the clearance is to make provision for a film of lubricating oil, the clearance should on this basis remain practically constant whatever be the diameter of the shaft. As a matter of fact, the clearance required for the film of oil is exceedingly small. Some engines will run silently with a fairly large clearance, while others, due to the steam distribution and the inertia of the moving parts, will knock audibly with a clearance of only 0.002in. Generally speaking, if the main shaft of a high-speed engine will just turn quite freely by hand, it will run perfectly when started up, and it must be remembered that when a double-acting engine is at work it will tend to make its own clearance, in addition to that left in the bearings when at rest, due to the fact that the metal from which it is made is not incompressible. Finally, there is the practical consideration that there is always a certain amount of risk in working close up to a danger point, and it has been the practice of the writer with high-speed, forced-lubrication engines from 50 to 2000H.P. to adjust the liners so that when the main bearing bolts are pulled hard home, the shaft, while still turning freely, just touches and marks the top brass. The caps are then removed, and an additional paper liner added on each side, its thickness varying from 0.003 to 0.01 in., according to the size of the engine. This practice has the advantage that after the engine has been started up and run for a short time the paper liner can be taken out altogether, or be replaced by a thinner one, should a closer adjustment be then required.

Before leaving the main bearings it will be as well to check the position of the oil holes in the crankshaft, with reference to the grooves in the main bearings, and make sure that the oil holes come opposite the grooves at the right time. When working on the crankshaft after these holes have been drilled, it is advisable to close the entrance to each hole with a piece of cloth, not waste. The cloth should be in one piece only in each hole; if there are two or more pieces in one hole there is a danger of one piece being left in when the final erection is taking place.

Before leaving the crankshaft there are the eccentrics and fly-wheel to be keyed in position. The usual method of keying on the eccentrics is to sink into the shaft a key with a gib at both ends. Like all other parts enclosed within the frame of a high-speed engine, it must be a practical impossibility for the eccentrics to come loose, nor must there be any danger of it working along the shaft. The class of key referred to is used to ensure this, since, provided that the two halves of the eccentric sheaves remain firmly held together, any circumferential or axial movement is impossible. In most cases the keyway as it comes from the machine has rounded ends, and these have to be squared with the hammer and chisel, the ends being left dead square with the bottom of the keyway. Each half of the eccentric sheave has to be bedded to the shaft, and the two halves of each sheave when bolted together must grip the former. If, when bolted together, they are not tight on the shaft, filing at the joint will not meet the case, because this will have the effect of decreasing the diameter of the sheave in one direction, whereas the working surface of the sheave must be truly cylindrical. For this reason the eccentrics should always be bored out a tight fit on the shaft. The writer is well aware that the same care is not taken with the eccentrics on many low-speed engines. It results from this and other causes that the eccentrics generally give more trouble through heating than any other part of the engine. The keyway in the sheave should now be tested for having its sides square with the sides of the eccentric sheave itself, using for this purpose a small reliable square. If the sides are not dead square as above, the half-sheave should be taken to the vice and the sides filed true. The sheave should then be laid upon the shaft, with its keyway coinciding with that cut in the shaft. Unless the edges of both keyways are parallel, the keyway on the shaft must be altered to suit. By this means it is ensured that when the key is let into the shaft the key will bear all along its sides. With a pair of inside calipers the width of the two keyways should be tested; that in the shaft should be, if anything, a shade the smaller, since the key will require to be a tighter fit in the shaft than in the sheave. The key is now to be fitted into the eccentric, the sides of the key being filed or scraped up until it pushes nicely into the keyway, the inner sides of the two gibs being filed up at the same time until the body of the eccentric will pass between them. The top of the key, however, is not fitted at this stage. The key is now to be let into the shaft, and the ends of the key filed down until the key will nicely enter the keyway. As it is possible that while working on the keyway on the shaft its edges may have been burred up a little, some marking should be rubbed in the bore of the eccentric, and the latter passed along the shaft in order to show up any high places. These, if any, should be removed; the surface of the shaft round the key should, if anything, be clear of the eccentric. The key should now be driven into its place in the shaft, and if the work hitherto has been carefully carried out, the key should nicely tap down to the bottom of the keybed. When the key is right home, which can be told by the ringing sound when struck with the hand hammer, it should be carefully caulked round with a sharp fullering tool. The top of the key is now to be carefully filed and scraped up until it beds on the bottom of the keyway in the sheave, at the same time that the sheave comes down on the shaft. If a good deal of metal has to be removed from the top of the key, the fitter need have no hesitation in using a sharp chisel and hammer, as there will be no fear of the key shifting in the shaft.

When the erector comes to fitting on the eccentric strap, he will again have to exercise a care that would be thought unnecessary on a slow-speed engine. With this class of engine the eccentric straps are usually slack, partly necessitated by the causes given above, and partly because the eccentric straps are seldom in true alignment. The result of the sheave being of an appreciably smaller diameter than the inside of the strap is that they are only in working contact at a single point on the circumference of the sheave, and matters are not helped by the relatively high velocity of the rubbing surfaces in the eccentrics of these engines.

With the high-speed engine, in order to obtain the long running without appreciable noise for which these engines are noted, it is essential that the wearing surfaces in contact be large in proportion to the work they have to do. Thus, not only must the straps be most carefully bedded to the sheave, but the methods of erection must be such that the alignment is assured, the strap always bearing full across the face of the sheave. As with the main bearings so with the eccentrics, a much closer adjustment of the wearing surfaces is required than with most other engines. The working clearances should not exceed from 0.002 to 0.003 in., or the thickness of the evening paper of the district. These eccentrics are, of course, supplied with oil under pressure, and the same precaution should be taken of seeing that the oil holes are fair.

The methods to be adopted in order to obtain accurate alignment of the eccentric rod will be dealt with later.

CHAPTER V

THE OIL PUMP

The pump used for feeding the oil under pressure to the various bearings of the engine is usually worked from one of the eccentric straps. In the larger engines more than one pump is used. For the purpose a lug is cast upon the strap, and is drilled for a pin which passes through the jaws on the end of the plunger. The motion of the eccentric strap is very suitable for the purpose. It will be seen from Fig. 1 that the pin actuating the plunger, when fixed as described above, is constrained by the motion of the strap to describe a path approximately in the shape of an ellipse, the plunger consequently dwelling a little on each end of the stroke. The pump itself is valveless, and varies in form, although the principle of its construction is the same in every case. In one design the plunger casing oscillates upon a trunnion, through which the oil is drawn and discharged. In another make the plunger works in a flat cylindrical casting, as diagrammatically shown in Fig. 1. The disc A which forms the barrel of the plunger oscillates in such a manner as to bring the open end of the barrel opposite the suction opening S in the casing during the up stroke of the plunger, and during its down stroke the barrel

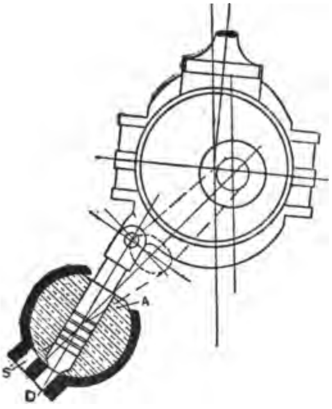

Fig. 1.

comes opposite the discharge opening D, through which the oil is forced to the various bearings of the engine. No packing is required with this pump, a few grooves turned circumferentially in the plunger being sufficient for all practical purposes. In order to prevent undue leakage of oil it is essential that the fitting about this pump be of the best, and as one or two oil-tight joints are required, a piece of paper is inserted in the joint in each case, and the thickness of this must be allowed for in fitting. In putting together such parts as these all joints should be put in place before the job leaves the bench, otherwise they are liable to be overlooked and the engine started up without them.

Since a nice fit is required in these pumps, and as there is no play between the plunger and the barrel, or between the disc and the casing, very careful alignment is necessary. The pump is usually fixed upon a planed facing in the crank-race, and the holes for the studs or set screws are usually marked off with the pump in position. The hole for the pump gudgeon is drilled after the two halves of the strap have been put together and turned up, so that the strap rests with one of its turned faces upon the table of the drilling machine. However, holes are not always finished truly at right angles to the surface of the table, owing to a possible lack of truth in the drilling machine, or to blowholes or other disturbing factors in the metal machined. In order that the plunger may work freely in the barrel, its axis must lie in the plane of rotation of the eccentric sheave on the engine shaft, and this should be ensured before either the strap or the plunger leaves the fitting shop. As a cut is almost invariably taken across the narrow facing D outside the strap during the same setting as that at which the strap was bored out, the latter can be laid upon two parallels on the marking-off table, with the machined surface downwards. The gudgeon can now be put through the jaws of the plunger and through the hole in the strap as in Fig. 2. If the finger of the scribing block be now applied to the top of the plunger, the points X and Y should be at the same height from the table. Although the axis A B of the gudgeon might be at right angles to the table in the view shown in Fig. 2, this axis may be considerably out of truth when looked at from the end of the plunger; and to make certain that the pump will work properly, the plunger should be swung round on each side of the position shown, and the scribing-block finger again tried at the points X and Y with the plunger in each extreme position. If the hole has been drilled out of truth in the manner indicated, the end of the plunger will approach the table in the one extreme position and recede from it in the other, as shown in an exaggerated degree in Fig. 3. In this case the only remedy is to reamer out the hole again and fit a larger pin. When this job has been passed as correct it may be sent into the erecting shop; and later on, the strap being found in place on the sheave, the plunger may be put into position and the pump tried in place. The two points to watch are, firstly, that the pump is at a proper distance from the crankshaft to give the correct clearance at the bottom of the plunger when the latter is at the inward end of the discharge stroke; and secondly, that the axis of the trunnion or disc, as the case may be, is parallel with that of the shaft. As the facing on which the pump rests has been planed at the same setting as the other upper surfaces of the bed, it is very improbable that it will be out of truth with the shaft. The truth of the oscillating portion of the pump with the machined under side of its base can of course be tested on the marking-off tables. However, to check its linability with the eccentric strap, the shaft may be turned round and the pump gudgeon tried into place with the strap in various positions, and if it goes in without any binding through the strap and jaws there will be little risk in permanently fixing the pump in the position found.

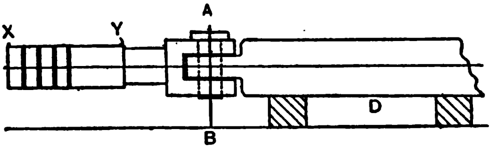

FIG. 2.

To return to the frame or standard of the engine—in some designs one of the outer crankshaft bearing caps carries a flange which is bolted to the standard, and in many cases the governor casing also is bolted both to the bedplate and to the standard. Where this is the case the standard must be fitted to the bedplate before the bearings are bored out. In other makes the bearings are independent of the standard. Before the standard comes round from the machine shop, all drilling and tapping that can be done conveniently at this stage under the machines will be finished. The joint between the standard and the bedplate must be oil-tight; in the early days of high-speed-engine manufacture great difficulty was experienced in keeping the lubricating oil within the casing of the engine. Mineral oil will destroy most jointings, and will find its way through incredibly small crevices; pure, straight mineral oil appears to be the only lubricant that will stand up for any length of time to the squeezing and pounding to which it is being constantly subjected on passing through its cycle of circulation, and at the same time fill the other requirements of a crank chamber oil. Not only is the presence of oil on the outside of an engine frame and bedplate objectionable as far as appearance is concerned, but oil rapidly destroys concrete foundations. In addition to this, a good crank-chamber oil, which must not thicken in use, and must readily separate from water, is expensive, and every effort is made by central-station engineers to keep the oil consumption at the lowest possible figure, for a preventable leakage will probably lead to a complaint being forwarded to the works.

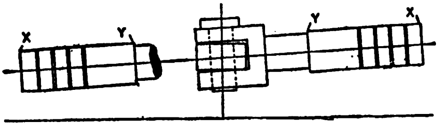

FIG. 3.

In the early days of forced lubrication the oil consumption was comparatively high, but with the more modern engines it can be brought down to one pint per 8000 H.P.-hours. The most satisfactory method of keeping an oil-tight joint between the standard and the engine bedplate is to have a good bed between the two metallic surfaces, and to use a jointing of ordinary paper. On the down-stroke of the piston the studs holding the standard to the bedplate at a point below the cylinder are in tension, and on the up-stroke this tension is released. Thus, if the bed between the surfaces at the joint is not a good one, and if, again, the total initial tension on the studs is insufficient to prevent it, an incalculably small working at the joint will be sufficient to cause an oil leakage. In order to get a true surface on the bed a good deal of care is required on the planing machine, but this is an easy job compared with getting a level surface on the under side of the standard. There is always a tendency for the less rigidly-supported parts to spring away from the tool, and the flange at the edge of the standard where insufficiently supported will often be found open at its outer edge when placed upon the bedplate.

CHAPTER VI

LEVELLING UP A BEDPLATE

BEFORE placing the standard in position the bedplate must be accurately levelled up. Although an engine can, if necessary, be lined up and erected with one end of the bedplate higher than the other—and such operations have not infrequently to be carried out with marine engines—it is a very distinct convenience to be able to rely upon the use of a simple spirit level and plumb-line when erecting other parts. The trouble and time spent in levelling up the bedplate are well expended. If the use of the above instruments is to be relied upon, the job of levelling up must not be tackled in a slipshod manner, and it must be carried out in such a way that its level will be maintained at least until the erection is complete. Wood, in the shape of either packing or wedges, should if possible be barred, and metal only used. Unless the supports of the bed be rigid, they are liable to give under the increased weight as the erection of the engine proceeds. Where machined cast-iron erecting beds are provided, these have been themselves levelled up when being fixed, and although their level is not always maintained, they are generally so little out of truth that all the packing required is a few pieces of paper, or at most a piece of thin sheet iron. In cases where more packing is required, the bed is usually first roughly levelled up on iron wedges, and except under special circumstances these should be three in number. Only in this case can the erector be sure that each wedge is taking its share of the weight, and the time spent in levelling up is thereby greatly reduced. The time taken in levelling up similar engine beds by different erectors varies so considerably, and the matter is so simply straightforward when systematically tackled, that the question is worth a brief consideration. In the first instance a reliable level must be obtained. Unfortunately the class of level usually found about erecting shops is inaccurate, and the base often untrue. Some are like the proverbial bricklayer's level, which reads level however it is held. For the present purpose the level should not be less than 18in. in length, and the best form is that in which the tube is adjustable at either end, so that the level may be set before starting the job. The curvature of the tube should be small, so that the movement of the air globule may be large for a small declination of the level from the horizontal. There is a level on the market in which the amount by which the surface under test is out of the horizontal in the length of the level is shown by lines upon the level at each side of the central position of the air globule. The reading is obtained by noting opposite which mark the *end* of the globule comes to rest, the divisions, which are large, indicating thousandths of an inch. The method of judging the position of the globule by noting the distance of its centre from a given mark is unsatisfactory, and if the erector has to keep turning the level about end for end in order to obtain a reading, it is a proof that the instrument is unsuitable for accurate work.

Accuracy in its absolute sense is of course unattainable in levelling up, as in other operations, but the workman should know within narrow limits what the amount of error is. Where tho enly level available is one of the ordinary type, provided that it is fairly sensitive and of a length not less than that given above, it may be made to answer for the present purpose by treating it as follows: Place the level upon any approximately horizontal machined surface, and put a mark upon the glass exactly above one end of the air globule. Turn the instrument end for end, and replace in exactly the same position. Place another mark over the same end of the globule in its new position. Now, provided that the movement of the globule is proportionate to the declination of the level, it is obvious that when the end of the globule dealt with is exactly central between the two marks, the surface upon which it is resting will be horizontal. A point that will be incidentally brought out is that the glass of the tube should be very thin, otherwise, if the observer looks at the level from a slightly different position, the globule will seem to have moved away from the mark. Warmth from the breath of the observer, or from contact of his finger with the glass, will by unequal expansion cause the level to give a false reading. The mark can be placed upon the glass with ink, or, if that is not available, with chalk, although the latter is more likely to be rubbed off. It is sometimes difficult to place a mark on the exact spot required, but provided that the mark is not originally too small, it can be pared down to correct size and shape with a knife or scriber point. Having placed a mark as nearly as possible centrally between the other two marks, which latter should now be erased, its accuracy of position should be checked by packing up one end of the level until the end of the globule comes under the new mark. The level should then be reversed end for end, and placed upon the same packing; and if the mark is still over the end of the globule, the former is in the correct position. If the mark is not over the globule, the original packing was either too high or too low, and the operation must be gone through again. By altering the packing, and possibly slightly modifying the mark until the level can be reversed end for end without the mark leaving the end of the globule, the result will be that the level will rest as nearly horizontal as the level itself is sensitive enough to show, and that it will read right whichever way round it is placed. Fig. 4 shows how the mark should be placed upon the level. Although from this description it might be assumed that the above is a lengthy operation, it is, on the contrary, but the work of a very few minutes.

In using paper for the purpose of packing, care should be taken to select only such as is smooth, clean, hard and uncrumpled. The erector will always find it convenient to have with him a supply of good paper of known thickness—in fact, it has almost become a necessity in connection with high-class work, and in many cases the workman who makes intelligent use of paper as a thickness gauge always comes out ahead of the man who relies upon a single set of feelers. There is no difficulty in obtaining an ordinary pocket-book with perforations along the inside of each leaf to enable it to be easily detached. The ordinary commercial pocket-book of this nature contains sheets which are wonderfully uniform in thickness, and a good quality paper with smooth-finished surface should be chosen, as the cheaper paper is often lumpy and otherwise unsuitable. The thickness of the paper should be carefully micrometered, and the result noted on the inside of the cover of the book. The micrometer used in the paper trade is constructed so that the paper being measured lies between two steel discs, the surface of which is much greater than the surface in contact with the paper when the ordinary fitter's micrometer is being used to gauge its thickness. Thus, when the micrometer is being employed on paper, the pressure applied by the micrometer screw should be light. There should be no difficulty in purchasing paper in the form described in thickness from 0.001 to 0.005in.

The present instance is a case in point with regard to the use of paper. Suppose that the bedplate resting upon packing placed at both ends is out of level, and it is desired to know by how much the packing must be increased at one point to bring the upper surface of the bed into the horizontal; suppose that the bed is 9ft. long, and that the length of the level is 18in.; it is evident that however much packing is required under one end of the level in order to bring the end of the globule under the mark placed on the glass, this amount must be multiplied by six in order to arrive at the amount of additional packing required under the end of the bedplate for the same purpose. Fig. 5 is a diagrammatic representation of the top of the bedplate, its assumed dimensions being 9ft. by 4ft. 6in. It is shown resting upon three separate packings A, B, and C respectively, and as they are only three in number each must be taking its full share of the weight. If more than three were in use, one or more of the packings might only just be touching the bed, and when the full compressive stress came upon them they might give a good deal, especially if the packing was com-

FIG. 4.

posed of several superimposed thin pieces of metal. The bed being roughly set, the erector should first go round the bed with his level and test its deviation from the horizontal at several different points as shown. Paper packing must be inserted under whichever end of the level it is required in order to bring it horizontal, and either the number of papers or their total dimension should be chalked upon the bedplate. A couple of chalk lines should be put on the bed at each reading corresponding to the positions of the two ends of the level at the time that the reading was taken. The reading should be at the same position as that in which the packing lay, so as to show clearly, as in the sketch, which end is low.

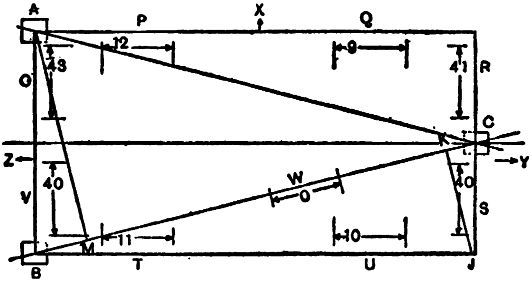

FIG. 5.

Referring to the readings as given, marked by consecutive letters from O to V inclusive, it is evident at once that the surface of the bedplate is not a true plane, since readings of 40, 43, and 41 thousandths respectively have been obtained in the same direction, the surface being on the twist. Needless to say, no alteration of the level of the three packings can make these three readings all alike. Before making any alterations to the packings, the readings should be very carefully considered, since the job is such that a great deal of time can be wasted in raising and lowering the packing by guesswork. In the first place, it will be noted that all the readings in the direction of X show this side to be low, also the readings in the direction of Y show that Z is lower than Y, and in order to correct the latter error it might be at first supposed that the packing should be reduced at C. Now, since there are only three packings, it is obvious that only two of them at most can be required to be altered in order to get the bed horizontal. The alteration of the packing at C would not help the readings O and V, packing A being lower than packing B. If packing B be altered, the bed will swing into its new position on the fulcrum line A, C. On the other hand, if packing A be altered, the bed will swing on the axis B C. Therefore the level placed at W on the line B C will throw fresh light on the subject. Assuming that the reading at W shows the bed to be horizontal along B C, a few moments' consideration and a simple calculation will prove that an increase of approximately ⅛in. added to the packing at A will bring the bed to as nearly level as practicable. This is so because the amounts of the upward and downward movements respectively at J and A depend upon the ratio between the lengths of the two lines K J and M A. The readings now obtained since the packing at A has been increased as suggested are approximately shown in Fig. 6. Wedges used for levelling should be of fine taper, smooth and greased upon the upper surface only before being used, otherwise they are liable to shift the bed horizontally when being driven in. Additional packing will now be required at different points under the bed. These packings should be tapped in tightly, but not with sufficient force to take all the weight from the three original packings.

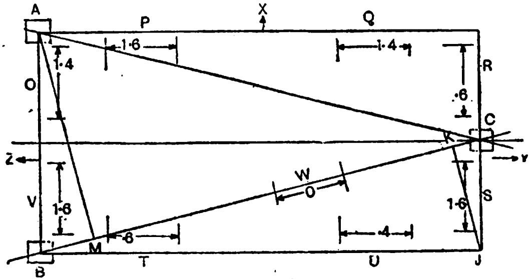

FIG. 6.

CHAPTER VII

FITTING UP THE STANDARD

BEFORE lowering the standard on to the bedplate, not only must all surfaces, the edges of which are likely to have been burred up, be rubbed over with a file, but both surfaces must be scrupulously cleaned of all grit and dirt. Although waste is used for this purpose in many shops, it is inferior to rag, and both are inferior to the human hand for a final rub, as the practical erector well knows. The frame being lowered into place, the erector should go round the job with a set of feelers and test the joint at both the inside and outside edges. It is not necessary to have a perfect joint with the standard just resting on the bedplate, as the flanges will spring a good deal when the joint is pulled up. Suppose that the maximum opening to be allowed is 0.003. In this case a No. 3 feeler will in every case be added to those inserted in the joint, but will not be read, the additional feelers only being noted. On his way round the job the erector should mark in chalk upon the flange of the standard the total thickness of the feeler in thousandths of an inch that can be inserted at the various points, always omitting the 0.003in. feeler for the reason stated above. This will be done on both the inside and outside of the standard. He will then go round again to see which was the point at which the highest reading was obtained, and it is at this point that no metal at all will be removed. Thus the figures, which do not state the actual amount of metal to be removed, should be rubbed out, and the thickness of the metal to be removed at each place substituted. This figure will be arrived at by subtracting the reading actually obtained at each position from the maximum. This is made clear in Fig. 7, which is purely diagrammatic, and shows in an exaggerated manner the opening between the standard and the bed.

It is usual before removing the standard from the bed to let the foreman see the amount of work that will have to be done, so that he can approve of its being started on or otherwise. This course is also a wise one from the erector's own point of view when there is much work to be done, since the foreman, having himself seen the requirements of the job, can make due allowance for the time spent. It may be stated in passing that the officials of some firms object to any work being done by hand on this joint, and depend entirely upon the accuracy of the machine work and the spring of the casting under the influence of the holding-down studs.

The frame being lifted away by the crane, the erector should see that it is placed in such a position as to be conveniently accessible for the use of his tools. An extra ten minutes spent in fixing the job in a desirable position may save an hour of his time in subsequent operations. The same applies to any packing which the erector may require to stand or sit upon in order to reach his work comfortably. It is false economy to be uncomfortable, and unless the workman can apply his full weight and keep a firm foothold without discomfort, the job cannot be done at the lowest possible cost. In commencing to remove the metal it is always best in such cases to adopt the same method as is used when chipping, although the amount of stock to be removed does not justify the use of the hammer and chisel. When chipping a surface down to a lower level—exceeding, say, $\frac{1}{8}$in.—the practice is to take a series of cuts first of all with a cross-cut chisel. Not only does this enable the metal to break away more easily, but it is also useful as a guide as to the depth of cut to be subsequently made with the flat chisel. The depth of cut made with the cross-cut is repeatedly checked as the work proceeds, either

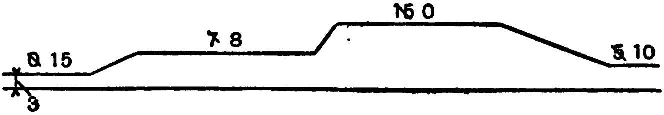

FIG. 7.

with a small depth gauge, or, if plenty of stock is to be allowed for finishing, simply by measurement with a small steel rule. Where this plan is followed the bulk of the metal can be removed with more confidence, and the erector, not being afraid to exert his strength, will finish the job in a shorter time.

Exactly the same reasoning applies to filing or scraping down a surface, if the amount of metal to be removed is of sufficient thickness to warrant it, and is not uniform all over the surface in question. Thus, in starting the job, the erector will proceed to sink the surface at a number of points in accordance with the dimensions chalked upon the edge of the flange. This, of course, can be done with a file; but generally speaking —especially if the surface be a wide one—the scraper is the tool to employ. As the operation proceeds, the depth of the groove is checked simply by placing an ordinary steel rule on its edge over the spot in question, and inserting under it from time to time the erector's feelers until the desired depth has been reached. In carrying out this operation a scraper of about one-half the width of the average flat scraper should be used, and it should be ground fairly square along its edge so as to cut an approximately flat-bottomed groove. The difference in the shape of flat scrapers for operating upon cast iron is very noticeable, and the reason for some of the shapes adopted is not very obvious. The way in which the average flat scraper is got up in a shop where a speciality is not made of scraping, differs from that which obtains in a first-class machine-manufacturing firm, where scraping is reduced to a fine art.

The cutting angle for a scraper for cast iron approximates to 90°, but this varies again with the hardness of the metal. The cutting edge should be slightly rounded, and upon the degree of curvature much of the success of the scraper as a cutting tool depends. With a given scraper ground to an angle much less than 90° one or two nice deep cuts can be taken, but the tool will then require regrinding. An incidental advantage of the angle of 90° is that the cutting angle will be the same on both sides of the scraper, and double the length of time will elapse before the tool requires to be reground. Of course a right angle cannot be obtained on both cutting edges unless the sides of the scraper are parallel, and in this fact lies the objection to those scrapers not infrequently to be seen which are forged out of thick stock and tapered down fairly suddenly to the cutting edge. Where there is a reasonable curvature of the cutting edge, not only can the workman touch one particular spot on the surface being scraped, but by slightly raising his hand a deeper cut can be taken, owing partly to the resultant downward pressure being greater, and partly to the fact that the width of the cut is reduced. A comparatively sharp curvature would obviously not be found on a scraper used for finishing, but if the workman's hand were to be lowered a flatter cut would be taken; but this would necessitate a sharper cutting angle.

The wear of the tool edge is the final factor in deciding the amount of metal that can be economically removed with a scraper in a given time, as the time spent in sharpening can soon reach a considerable proportion of the total working time. It was for this reason that the erector was advised in an earlier chapter to get and retain cutting tools made of the best quality steel. The erector should also endeavour to keep an oil-stone beside the job, so that he can touch up his scraper without leaving his work. A smooth oil-stone is of but little use for this purpose, and a really rapid cutting stone should be selected. Every time that the side of the scraper is put on the stone the cutting angle is made more obtuse, and where this is done the scraper should be laid flat upon the stone to commence with, the hand being only very slightly raised as the edge wears down, so as to keep the scraper in work as long as possible without regrinding. To get good results the scraper should be held up vertically over the stone, and the cutting face rubbed up keen and smooth at its edges. If a file is used for the above purpose it should be a narrow one, and while in use the file should be moved on its cutting stroke in a direction as nearly as possible at right angles to the direction of the moving file used subsequently for roughing-off the stock. The reason for this is that the tooth marks left by the first file will stand out clearly from the rest of the surface, and the erector can thus see at once when he has worked down to the desired depth by the subsequent file marks commencing to show across those originally made.

In order to remove the metal rapidly with a file an ordinary flat rough file is not the best tool to use in cases such as this, in which the surface of the stock under the file is large. A much better tool for roughing under such circumstances is the square file, which, having a much less cutting width than the file previously referred to, enables a greater pressure to be applied per square inch, and consequently freer cutting results.

Another point worthy of attention is the formation of file handles. When chipping with a strange hammer, a fitter will often find that he has blistered his hand after a spell of work, whereas with a hammer the shaft of which he has become accustomed to, he could do many times the same amount of work without discomfort. Where heavy filing is involved a similar state of affairs exists. For this reason the fitter should carefully select his file handles and keep them by him. They should all be similar in shape to a specimen file handle which he has found to suit his hand, and should be free from any irregularity or roughness.

Assistance can often be gained on the job under discussion by the use of a broad-edged straightedge, along the edge of which a little marking has been thinly applied. It is seldom that any serious deviation in a short length from a true plane will be found in the surface of the bedplate, owing to its rigid construction and less likelihood of springing under the tool, the machined portions being well within the area of its base. Consequently a short straightedge, when laid across the surface on the standard which is being operated upon, can be brought down to rest upon the bottoms of any three of the grooves made to guide the erector in his work. When this job has been completed as far as possible, the standard should again be placed upon the bed and carefully checked. If the readings were intelligently taken in the first instance, little further work will be required on this job. It is better to fit the inspection and access doors on to their faces on the standard before the studs are screwed in, as the erector is then able to give the door a rub on its face with a little marking. This enables a nice job to be made of the joint, which can then be faced up to the marking.

In the early days these doors never seemed to be tight, and there was generally a considerable leakage of oil at these points. This was perhaps aggravated by the fact that many of the early doors were hinged on to the standard. It was the difficulty of maintaining a hole-tight joint with a hinged door that led many firms to abandon their use. With fairly closely pitched studs an excellent job may be had. Where hinged doors are used a good deal of care must be used in fitting the hinge pins. After the doors have been bedded in on the standard, they are cramped down in position and the holes in the hinge on the door are marked off and drilled. A drill smaller than the size of hole actually required is used to allow for reamering in position. Now it is evident that if, after the hinge pin is in place, there is the slightest opening in the joint at the hinge, however tight the catch on the door may be, it cannot pull the door up at the hinge. Therefore it is better, before setting the door for running the reamer through the hinge, to pack the door away from the standard at the other side with several thicknesses of paper, their number depending upon the size of the door. Thus, when the hinge pins are put into position, the door on being closed comes first into contact with the standard at its edge nearest the hinge, and has to be sprung down to its face at the other edge with the catch. This ensures a good joint throughout. If the engine is a large one, and carries a platform on the standard, it is better where possible to fit the brackets while the standard is on the floor. The fitting up of such platforms is generally regarded as being more or less of a rough job, but a good deal of intelligence is required to carry the job through with success and dispatch. Nothing catches the practised eye sooner, or looks worse, than a platform or handrailing that is out of truth or sprung in any way.

In erecting the brackets to carry the platform it is usual to lay a long straightedge across the top of the standard and make all the brackets parallel with the straightedge and at the same distance from it. If this surface is properly worked to there should be no fear of an unsightly job. The standard is now set to the centre lines scribed upon itself and upon the bedplate, and care should be taken that the holding-down setscrews or studs, as the case may be, are well clear at the edges of the holes in the standard when the latter is in its correct position. Otherwise there is a danger of shifting it slightly when pulling it down on to the bedplate. In cases where the standard is independent of the bearings as far as position is concerned, the standard is often set when lining up the cylinders. Whatever may be the case in this respect, steady pins are required to keep the standard in position, and the holes for this purpose have to be drilled in the bedplate through the existing holes in the flanges of the standard. Although practice varies in this respect, the best form of steady pin in cases such as the present, where the bottom end is not accessible for driving out, is the taper pin fitted into a reamered hole. Where the big end of such a pin is made square or hexagonal to take a spanner it can always be lifted out by giving it a slight turn, and at the same time applying a slight upward pressure. When the erector is fitting these pins, a good plan for checking their taper against that of the reamer is to obtain from the tool stores two external cylindrical gauges which, though differing slightly in internal diameter, will go on the small end of the reamer, yet neither of which will pass over its large end. When both of these are put on the reamer—the larger of the two, of course, being put on first—there will be a certain distance between the two, depending upon the taper. Unless the same distance between the two gauges when similarly put upon the turned pin is obtained, the taper of the two is not identical. Owing to the taper, the position of the standard upon the bedplate can very readily be re-located.

CHAPTER VIII

WORK ON THE CYLINDERS

Before the lining up of the engine can be proceeded with the cylinders will be required. These will come round from the machine shop along with the cylinder distance pieces and crosshead guides, all ready machined. The two latter are generally cast in one piece, the top of the cylinder distance piece forming the bottom cover of the cylinder. Before any more work is done upon the cylinders they should undergo the hydraulic test, since if they failed in this all previous work would be thrown away. Hydraulic testing is generally carried out in a separate part of the shop, as there is naturally a good deal of water about, which is liable to cause rust and other damage if used for the above purpose in the middle of an erecting shop. Further, with a separate section of the works laid off for this purpose, a plentiful supply of water can be laid on, and proper provision can be made for the drainage of waste water. Where the amount of work to be done warrants it, drainage tiles should be laid down to form the floor, with a natural fall to take away the water. By this means the workman's feet are kept dry, and spanners and other tools that happen to lie on the floor are kept free from wet or rust. A good flexible hose-pipe should be provided for rapidly filling up the castings to be tested.

In order to test the engine cylinder, the distance piece must be jointed up to the former, and this joint can generally be permanently made, as the one is usually registered to the other by means of a spigot and faucet. The ends of the piston-rod and valve-rod stuffing-boxes are sealed by means of temporary flanges. The cylinder cover is jointed up, and all tapped holes such as those for the indicator cocks, escape valves, etc., except such as are required for other purposes during the test, are closed with screwed plugs. A valve is screwed into the highest points or point of the casting, in order to allow for the escape of any imprisoned air, and at the lowest point it is advisable to have a cock for draining the water after the test is completed. This is much preferable to the usual practice of easing back a flange in order to allow the water to escape, as the water usually squirts out under the influence of the head above it, and lands somewhere where it is not wanted. The valve-chest or some other cover is left off until the last, so that the hose-pipe can be inserted for filling. The cylinder must rest upon trestles or be packed up from the ground by other means, so that it may easily be examined in every part for the escape of water when under test. After the cylinder has been filled the valve-chest cover will be jointed up, the air cock, or cocks, opened, and the pump started up. The air cock should be kept open until water begins to issue from it, and then closed. The water should be pumped to test pressure, which is usually double the working pressure, and kept there while the cylinder is being examined. Leakage will generally take one of two forms. It will either spurt out in a fine jet, which usually means a blow-hole, or it will stand out in beads on the surface, which increase in size until they trickle down its sides. In the case of a blow-hole, unless the jet is a large one, an attempt may be made to caulk it; but it is better in the first instance to let the water off and allow the job to stand for the night. It will often be found in the morning that the small leakages have disappeared, having rusted up during the night. Most inspecting engineers insist that no caulking of any description be done until they have seen the job under test, and unless the caulking of cast iron is carried out with great judgment it can always be detected by a smart man. Where the metal is spongy the caulking tool quickly sinks into it and leaves a mark, and leakage due to sponginess will generally take up more effectively if a little salammoniac is dissolved in the water, and pumped under pressure through the metal. This greatly accelerates the rusting process. In the case of a pin-hole it is generally best to drill and tap a small hole, and after screwing in a plug, to file it flush. Cast-steel cylinders are much more easily caulked with a nice round-nosed punch, and the writer has known a squad of fitters to work on a cylinder at this job for several days.

As soon as the casting is found to be tight and passed as satisfactory by the proper authority, the water should be run off and the machined parts carefully wiped down. Especially is this necessary where salammoniac has been used, as a very minute quantity in the water will cause it to rust the bare metal wherever it comes into contact with it. After all temporary tackle has been removed and everything wiped dry, the cylinder and its accessories can be returned to the erecting shop. It may be remarked in passing that in the testing department should be kept a liberal supply of joints, screwed plugs of various sizes, and temporary flanges for testing purposes. They should be carefully and conveniently stored, so that no delay may occur in the erector finding the material that he requires, and he should exercise equal care in returning the material when the job is completed. In cold-water testing there is nothing to beat indiarubber as the main constituent in the jointing material used. It is not easily damaged in use, and makes a good joint.

There are one or two little jobs that still require to be done on the cylinders. If the engine is a large one, the probability is that liners will have to be put into the valve-chests. Now that solid or "limit" packing rings are largely used (in small engines no rings being provided at all), much depends upon the accuracy of the machine-work. With modern machine tools the liners should be finished externally and internally within 0.001in. of truth and size. The ordinary Ramsbottom ring which was used at one time in high-speed engine piston valves has been abandoned. Whatever may be its advantages in the cylinder, it had to meet different conditions in the valve-chest, including passing over port openings, and breakage of rings was a frequent occurrence. Although it might appear at first sight that a solid piston valve would not long remain steam-tight, it has been found in actual practice that after years of work the valves are practically as tight as when first put in. A piston valve in a vertical engine is really floating, and different conditions would obtain if the engine were horizontal. Another job is the fixing of screwed drain cocks, blow-off valves, etc. When these are first screwed up it generally happens that they require to be turned through a further fraction of a revolution before they are in their working position. This means that metal must be removed from the face against which the shoulder rests. Unless the thread on the fitting has been undercut to its base close up to the shoulder, the hole in the cylinder should be well countersunk to make quite sure that the shoulder comes hard down on the face.

The general experience is that those fittings that do not require to occupy any particular position circumferentially, but can simply be pulled up home, never give any subsequent trouble through leakage. This may probably be accounted for by the fact that the facing tool generally leaves the face a little hollow round the hole. The facing cutter will wear more quickly where the cutting speed is greater, which is at a point farthest away from the centre of the bar. The facing thus being hollow towards its centre, holds the jointing material better, since it cannot well be blown out by the steam. When the surface has to be re-faced it is worth while spending a little time to make a good job, since if too much metal is accidentally removed, the fitting may have to be turned round another complete revolution. The fitting should not be pulled hard down on the face with a spanner in order to mark any possible high spot on the face, since if the face is actually high on one side, this practice puts a severe strain on the nipple, and many have been broken in this way. Very little force is needed to get the shoulder to mark on any high spot, and more force than is really necessary only produces a false marking.

It will generally be found that a small flat scraper may be used with advantage in finishing off this job, which is one that in spite of its simplicity has cost many an otherwise good erector his job.

CHAPTER IX

THE USE OF LINE AND TRAMMEL

ONE of the main objects in the design of the modern high-speed steam engine is cheapness in manufacture, and the result is that it is one of the simplest to erect. The usual practice is to incorporate the bottom of the cylinder with the cylinder distance piece and crosshead guides. In this case the alignment is automatically made between the cylinder and the crosshead guides by means of a spigot turned on the latter casting which fits into the counterbore of the cylinder. Sometimes in the larger sizes the crosshead guides form a separate casting. In this case the guides are registered to the cylinder distance piece by means of a spigot and faucet. Thus, provided that the machine-work is truly carried out, the only lining-up required is to place the cylinder and guides on to the standard or frame of the engine and shift the former until the centre of the cylinder bore comes over the centre of the crank-pin when the latter is in its highest or in its lowest position.

Unfortunately, all machine-work is not good, and the liability of error is greater with large engines than with small ones. In machine-work there is a tendency for the amount of the error to be proportional to the dimensions of the machine surfaces. For instance, one would not expect to get the same accuracy of bore in a cylinder 7ft. in diameter as would easily be obtained in a cylinder 7in. in bore. Further, any error in the machine tool performing the work would increase as the points of measurement were further apart, and in addition to this the larger engine castings are generally less stiff proportionately than small ones, and consequently spring more under the tool. The amount of error anticipated often decides both the method of erection and the order in which the jobs are tackled, and as the quality of the machine-work turned out varies considerably with different firms, so the methods of erection vary. Were all firms equally well equipped in the way of tools, the results might be different.

At the same time, it is very essential that the ambitious erector should fully grasp the principles involved in the lining-up of engines, and should realize under what conditions of error they will run satisfactorily, and in which cases future trouble may be confidently anticipated. Many engines are constant sources of trouble and annoyance with hot and rapidly-wearing bearings, and either the lubricant used or the engineer in charge is often unjustly blamed. In a very considerable proportion of mill engines there is some bearing which the slightest change in the lubricant used, or the smallest departure from normal conditions, will cause immediate heating up. In almost every case this sort of thing is due to inaccuracy of construction—to some error in original truth and alignment.

In order to get a line through the centre of the cylinder bore, a common practice is to use a " centre " consisting of a piece of wood in the centre of which a piece of sheet tin has been tacked. This wood " centre " is cut so that it will drive tightly into the tapered counterbore of the cylinder. The actual centre is found by trial and error—scribing three arcs upon the surface of the tin with " jinnies " or with a pair of trammels. The radius described by the instrument is altered until with one leg resting against the cylinder walls successively at three equidistant points three arcs are formed upon the tin, which intersect one another at one point. This point will be the centre of the cylinder. In describing these arcs there is no need to put a heavy pressure upon the point of the trammel or instrument used, only very fine lines being required, and the trial arcs are only temporary. The point should be ground very fine, so that the point of intersection of the arcs can be clearly seen. The trial lines should now be rubbed out with a piece of No. 0 emery cloth, and the final correct lines inscribed. A mark should now be made at the point of intersection with a fine scriber, but should only be deep enough to hold the trammel point and not be punched through the metal.

The accuracy of the point found should now be checked by placing the point of the trammel in the fine centre made, and trying the finger of the trammel against the cylinder wall at no fewer than three equidistant points.

All being found correct, a hole can be reamered through, but should be made no larger than actually required for the passage of the line. One end of the line is passed through the hole, a small nut, or something that will serve equally well, being tied to the other end to take the subsequent weight of the plumb-bob or other weight required to pull the line taut. If the diameter of the cylinder is large, the trammel will probably be more convenient to handle than the " jinnies "; but a little care is necessary in holding the trammel bar, or serious mistakes may be made. As a trammel is a good deal used for transferring measurements of large dimensions, the point is worth considering. If a pair of ordinary trammels are put upon the ordinary wooden bar and rest with their points upon a surface, it will be found that the points can be brought nearer together by bowing the bar upwards in the centre of its length, and that the points can be made to move outwards by causing the bar to sag downwards in its centre.

Thus, if the points of the trammel be set to some particular dimension by applying them to the upward face of a rule lying upon a marking-off table, and the dimension be transferred by means of the trammel to the under side of some beam, the trammels being inverted for this purpose, it will be found that the dimension has been considerably reduced in the process. This is shown to an exaggerated degree in Fig. 8. The longer and more resilient the trammel bar, the greater the difference in measurement between its points that can be produced by the way in which it is held.

In making use of a vertical line, the ordinary coarse, uneven string should be avoided. The line should have a perfectly smooth surface, for if frayed it is difficult to work up to it by sight with a point gauge. Possibly the best line to use is the steel wire known as " music " or " piano " wire. In order to draw this wire out taut it should be loaded up to not less than one-third of its breaking strength. Great care, too, should be taken in storing it, as owing to its spring it very easily becomes hopelessly entangled, and unless wound on a bobbin of fairly large diameter it is not easy to straighten. The bobbin, too, should have large flanges, otherwise the wire is likely to spring off when being unwound. Should the wire from any cause become kinked, that particular length may as well be thrown away, since it will break before it will come straight. In order to prevent the line from swinging when touched with the point gauge or accidentally moved in other ways, it is a good plan to immerse the weight in a can of oil of fairly high viscosity, which will at once stop any pendulum action. A good deal of practice is required to work rapidly and accurately to a line. The sense of sight can also be helped by that of touch, but the best way in which to appreciate the narrowing space between the adjustable point gauge and the line when the former is being gradually set up to the latter, is to have some light surface behind the line, such as a piece of white paper.

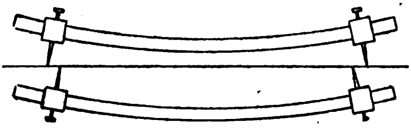

Fig. 8.

Referring again to the wood centre, it is quite possible that as fitted this will not be sufficiently rigid to carry, without danger of shifting, the weight that would be advisable for use with the steel wire, and in this case it may be replaced by some form of bar resting upon packing across the top of the cylinder. In fact, many erectors prefer this plan, moving the bar about while setting the line by means of a point gauge to the upper part of the bore of the cylinder. Either the weight of the bar is depended upon for keeping it in position, or it is cramped down, employing for this purpose the studs to be subsequently used for holding down the cylinder cover. Where several sizes of engine have been standardized it is an easy matter to arrange a suitable casting for carrying the line, and various sorts of special tackle for facilitating this work can be made and kept at hand. The point below, through which the line has to pass, lies somewhere along the imaginary axis of the crankshaft and in the axial centre of the crankpin. There are many ways in which this position is marked. In some cases it is designated by the intersection of a straightedge with a wire line passing through the centres of the bearings In other cases it is scribed upon a flat iron bar provided for the purpose and let into the crank-race; but however this position is denoted, it can be found by measurement from the centre of a convenient bearing along the axis of the crankshaft.

Let us suppose that an ordinary plumb-bob is to be used, and in this case the bottom position referred to will be most conveniently denoted by the intersection of two lines at right angles to one another. The object now is to move the cylinder and crosshead guide so that the point of the plumb-bob is just above the intersection of the two lines in question. In the first place, it is not easy to see when the point of the plumb-bob is correctly placed with reference to the two lines; and, secondly, there is no way of stopping the swinging of the plumb-bob except by attempting to steady it by the hand from time to time; and, thirdly, there is often delay caused by the stretching of the line. Further, every time the cylinder is moved or the line is touched with a point gauge, the line will again commence swinging. Again, there is no visible multiplication of the error as there is with the method to be mentioned later. For these and other reasons it is a quicker and better plan to have the line pass right through the point in question, and to suspend the weight in a tin of oil as mentioned above. This will not only damp down the natural swinging of the line, but will neutralize any vibration of the shop due to running machinery.

A fixture found useful for locating the centre of the crankpin was a simple casting which fitted in between the bearings and was adjusted and locked in position by means of set-screws. A small hole was drilled in the jig, which was so adjusted that the point in question came in the centre of this hole. A small bush was fitted into this hole, and another hole just large enough to take the wire line was drilled in the centre of the bush. Permanent scribed lines at right angles to one another and passing through the centre of the bush were put upon the fixture in order to facilitate its rapid setting in position. When the line had been threaded through the small bush and hole, and was firmly fixed in position in the centre of the cylinder, at its upper end, it would probably be found that the line was resting against one side of the hole. From this, without making any description of measurement, it would be obvious in which direction the cylinder should be moved, and its movement in this direction could be continued until the line swung clear from the side of the hole and assumed a position approximately in its centre. The line could then be very accurately centred from the register shown in Fig 9.

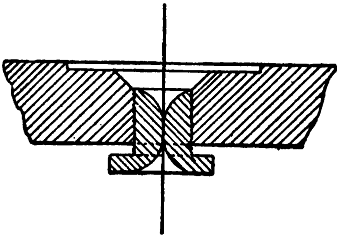
FIG. 9.

It should be noted that the distance gauge being first set up to the line where nearest to the side of the hole, and then placed on the opposite side of the line, the apparent error is doubled. There is now a steady, absolutely vertical line hanging from the top centre of the cylinder, and any deviation from the vertical either in the cylinder walls or in the surfaces of the crosshead guides can be detected at once with the point gauge. The amount of deviation from he vertical is measured by adjusting the point gauge to the smallest dimension between the line and the surface, and then at the point where the dimension is greatest packing out the end of the point gauge from the surface with thickness gauges or with paper until the other end of the point gauge is brought up to the line.

CHAPTER X

ERRORS IN ALIGNMENT

Now, it is quite possible that owing to some error in machining, a truly vertical line could not be put exactly concentric with both cylinder and crosshead guides, and yet *some* straight line could be got to do so and pass through the centres of the shaft and crankpin by simply shifting the cylinder upon the standard. It was to enable this to be done that the small drilled bush was used, and by inserting it in the fixture, the line, sliding in the bush and kept taut by the weight, will be constrained to pass through the required point however the cylinder and other parts of the engine may be shifted about. At any time the bush can be removed, and with the line swinging freely in the larger hole the deviation of the former line from the vertical can be tested.

For the sake of clearness in what follows, this line passing through the fixed bush will be referred to as A, and the freely swinging plumb-line will be denoted by the letter B. Of course line A may be vertical, but in any case that would only be an incidental property of the line, its main qualification being that it passes between the centre of the top of the cylinder and through the axis of the crankshaft, and through the centre of the crankpin when the latter is rotated until the centre of its axis cuts the line. The point where this line passes through the axis of the crankshaft will be known as C.

In Fig. 10, in which, as in the following figures, the errors are greatly exaggerated for the sake of clearness, the actual amount being of course very small, the plumb-line B is quite concentric both with the cylinder bore and that of the crosshead guides, but it drops at some distance behind C. Now, the obvious thing to do would appear to be to shift the cylinder and guides bodily towards C. This would, of course, generally be possible, but supposing that in this case more than one cylinder and valve-chest were bolted together, and that the movement would involve other expensive operations, a little consideration will make it evident that the engine would run perfectly as it is. Under normal conditions the running pressure would be on the side of the crosshead marked X, and only after steam was shut off and the inertia of the revolving parts was driving the engine, would the crosshead come over on the up-stroke against the guide marked Y. In fact, there is a standard make of single-acting engine designed for high rotative speeds on the market in which the centre of the cylinders is moved back from the axis of the crankshaft by an amount equal to the throw of the crank. The idea is that by keeping the angularity of the connecting rod towards the back side of the crosshead the pressure on this side is always maintained, although the engine is a single-acting one. In the present case the pressure on the guide X would be slightly increased when on the down-stroke, and slightly decreased on the up-stroke. This amount, however, would be infinitesimal and not worth considering, as the amount of the errors being dealt with is that to be found in ordinary erecting-shop practice. In the same figure D denotes the centre of the top of the cylinder bore from which the line is suspended.

In Fig. 11, lines A and B coincide, both passing centrally through the cylinder and stuffing-box, but not through the centre of the crosshead guides. Careful testing with the point gauge shows that although the line is not in the true centre of the guides it is quite parallel with them. If the guides are cast in one piece with the distance piece and spigoted to the cylinder, the only way of bringing them both into line would be to file some of the stock off one side of the spigot. As this joint would probably have been permanently made, it would be an expensive job to commence filing this spigot on a large engine.

There is, however, another method by which the job can be made to run perfectly. It is considered good practice to place a little thin packing between the slipper and crosshead, and so to arrange it that it can be increased as the slipper and guide wear. Thus, in this case the amount of packing would have to be decreased under the front slipper and increased under the back slipper. So doing would maintain the crosshead in line with the cylinder bore. Although, as in the previous case, the working crosshead guide is moved back from the axis of the crankshaft, it should be noted that the pressure thereon is not increased during the down-stroke, since this pressure depends upon the angularity of the connecting rod, and in this case the angularity has not been affected.

Should the axes of the cylinder and guides respectively neither coincide nor be parallel, as in Fig. 12, it is impossible for the job to work in this condition if the error be at all serious. The tendency would be for the piston to touch the walls of the cylinder at M at the bottom of the stroke, and at N at the top of the stroke, and if the total clearance between the piston and the cylinder be not greater than the horizontal movement of the crosshead, the piston would strike the cylinder walls. This actually occurred in the low-pressure cylinder of an engine installed in an electric-supply station in the South of London, and the cause of the noise was for a long time a mystery to the engineering staff. There will of course be a lateral movement of the piston rod in the gland, and the neck ring in the stuffing-

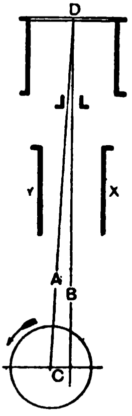

FIG. 10.

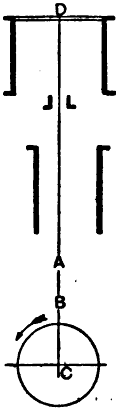

FIG. 11.

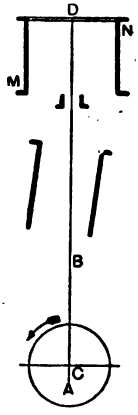

FIG. 12.

box would have to be a sufficiently loose fit to allow for this movement, or there would be trouble with the rod.

This fault is not infrequently come across in the large horizontal engines in the Lancashire cotton mills. The finger of a scribing block fixed against the rod in such cases will show a considerable vertical movement of the rod in the gland, and this, if not due to the rod being bent, is probably accountable by the crosshead slide not being parallel with the bottom of the cylinder on which the piston is running. Such a movement might of course be also due to the crosshead being either higher or lower than the piston. In any case, the fault here being discussed cannot be accepted, as it interferes with the proper working of the " piston line."

In Fig. 13 the stuffing-box has been bored out of centre with the bore of the cylinder. This is an uncommon but not unknown error, as the two operations on the machine are completed at one setting, where the stuffing-box is cast solid with the cylinder, and it would appear difficult to make the error even if the stuffing-box be cast along with the distance piece. There might be a tendency on the part of the erector to attempt to move the cylinder towards Z so as to bring the line into the centre of the stuffing-box. This would, however, create complications with the guides. The nearest distance of the neck ring from the line must be carefully checked to make certain that it will not touch the rod, as this is a frequent cause of hot and bent piston rods. If the clearance is not sufficient, either the neck ring must be eased out at that side, or an eccentric neck ring may be specially turned. Where metallic floating packing is used it will to a certain extent accommodate itself to the position of the rod, but in the case of an ordinary gland, if eased at one side, there is a danger of its being put back after the gland has been packed in a different position, so that it is better to bore out the gland a little larger. The above is an objectionable error.

The error shown in Fig. 14 is generally due to the top of the standard not being planed truly parallel with its bottom surface. This is an instance in which it may be possible to ignore the plumb-line B and work to the line A. If this error is small, it may be possible to shift the cylinder and guides towards K until the line A between the points C and D passes centrally through them. This is shown in Fig. 15. In this case the piston line should work correctly. Of course, where the crosshead guides are incorporated with the cylinder, the engine would have worked with the cylinder in the position shown in Fig. 14, although neither the plumb-line B nor the line A passed centrally through them. However, by moving the cylinder and guides into the position shown in Fig. 15, the relative truth of their surfaces can be checked, as also the truth of the stuffing-box. This being ensured, the cylinder can either remain in this position or be moved into some more suitable position. In both positions given the angularity of the connecting rod with reference to the guides is altered.

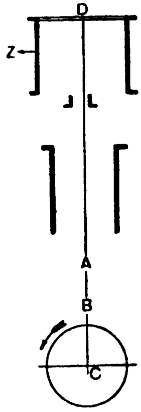

FIG. 13.

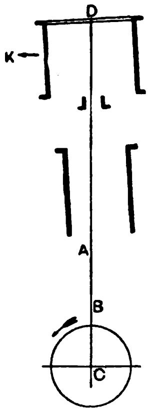

FIG. 14.

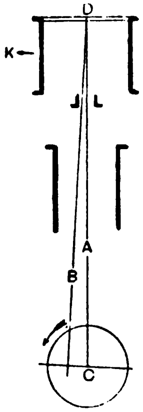

FIG. 15.

The error shown in Fig. 16 was a contributory cause of a serious accident. It will be seen that the crosshead guides, while axially true with both lines, have been bored out taper, the larger diameter being at the bottom. As the crosshead slipper runs on only one guide at a time, the effect is virtually the same as in Fig. 12. This error existed in the guides of the low-pressure cylinder of a 1000kw. engine in a South of England power station. The low-pressure piston was of cast steel, and as it afterwards turned out was a neat fit in the cylinder. The piston when the engine was under load would approach the cylinder walls at M and at N provided that the piston was central in the cylinder at half-stroke. If, on the other hand, the piston was central when at the bottom of its stroke, it is possible that if the error in the guides was great, and the clearance round the piston small, the piston would be bearing against the side of the cylinder marked N during the greater part of the stroke.

This engine had been under load running on the condenser during the afternoon, and in the evening, after being changed on to the atmosphere for about half an hour, the piston seized up in the cylinder and wrecked it. Of course cast steel will expand more than cast iron when heated, and matters may have been made worse by the fact that the mean temperature in the cylinder was higher with the engine exhausting into the atmosphere than when on the condenser. The side of the cylinder N proved upon subsequent examination to have been badly scored. Matters would not have been put right by altering the angle of the guides so as to bring the ahead-going guide parallel with the cylinder bore, because in this case the other guide would have been made worse, as shown in Fig. 17. When the plant was running with its own inertia after shutting off steam, the crosshead would come over on the up-stroke on to a guide in which the error had been exactly doubled, although in this case the resultant pressure would only be that due to the weight of the reciprocating parts.

The same error was the cause of a great deal of trouble and annoyance in another station, although in this case the guides had been bored out with the larger diameter at the top.

In all these cases so far it has been assumed that the crosshead guides were cylindrical, because with one or two exceptions this is the universal practice with high-speed engines. It is cheaper to machine and erect, but liberties in alignment which might be taken with flat guides are out of the question with the former type. Where the crosshead guides are bored out taper, it is obvious that the surface at one end will be struck with a larger radius than the other. Thus, if the slipper is carefully bedded to the surface of the guide at the large end, it will when pushed up to the small end only touch at the outer edges, the centre being clear of the guide as at B in Fig. 18. If bedded to the smaller end of the guide the slipper will only touch down its centre at the larger end, the edges being clear as in Fig. 18 at A. This was the cause of the constant heating of the slipper of the engine referred to. When the slipper was tried on the guide with marking, and pushed from one end to the other, it of course showed an excellent bed. The trouble was only cured by scraping out the guides at the small end.

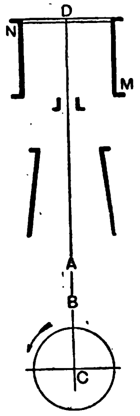

FIG. 16.

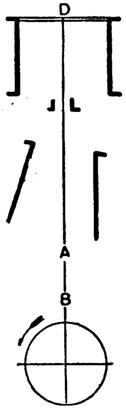

FIG. 17.

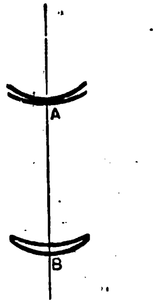

FIG. 18.

Now the errors in alignment dealt with so far have all lain in the plane of rotation of the crank, and must in no way be confused with similar errors lying in a plane at right angles to the above. It will also have been noted that absolute linability to a plumb-line is not in every case essential to good running.

Dealing now with errors of alignment in a plane at right angles to that of rotation of the crank, Fig. 19 shows an error similar to that in Fig. 10, the crosshead guides and cylinder walls being co-axial, but the plumb-line B does not pass through the centre of the crankpin. Line A is of less use in dealing with lack of alignment in this direction than was previously the case, but by pulling out the bush in Fig. 9, line A at once becomes the plumb-line B. Now, the sides of the crankpin brasses should be quite clear of the crank-webs, and there should also be a clearance at both sides of the crosshead brasses. Also, in making any adjustment it must not be overlooked that if the slipper is properly bedded to the slide, there is no possibility of any play or movement of the crosshead (with the circular guides) in the direction of the axis of the crankshaft. The working pressure forces the crosshead into the back of the guide, and is thus constrained to move in one predetermined straight line. Now, in the average high-speed enclosed engine, any such error as this is seldom of serious proportions, and can almost invariably be allowed for in the side clearance of the crankpin brasses.

This error generally arises when two or more cylinders are bolted together and the dimension between their centres differs from that between the centres of their respective crankpins. In such cases it is impossible to improve matters by any bodily movement of the cylinders, the best result being obtained by dividing the error between the two crankpins. In the larger sizes of the marine-type central-station engine this error is much more frequently found. The cause for this is the fact that in bolting up together several cylinders and their valve-chests, there is the danger of the sum of comparatively small errors reaching a considerable total. In the larger sizes of the totally-enclosed high-speed engine each cylinder stands by itself with its own valve-chest.

In the former type of engine the method of procedure is to throw the connecting-rod brasses to suit, a process that will be dealt with later. Fig. 20 corresponds with Fig. 11 in the previous series. The plumb-line B falling naturally from the point D through the point C passes centrally through the bore of the cylinder, but is eccentric with the guides. The solution is not so simple as in the case illustrated in Fig. 11, but if the error is sufficiently great to make it possible for the piston to touch the cylinder walls, it must be removed. Probably the best thing to do under the circumstances is to file the side of the spigot so as to move the guides with reference to the cylinder. Owing to the way in which they are machined, any eccentricity in the guides would probably be accompanied by a similar eccentricity in the stuffing-box, it being assumed in this case that both form one casting. Thus, one movement would put both errors right.

However, in Fig. 20 the stuffing-box is shown central. In such cases it is frequently possible to put the piston rod in the centre of the guides, as follows. When the slippers are machined, they are turned in the lathe central with the axis of the piston rod. If the surface on the crosshead whereon the slippers rest is a plane surface, it is sometimes possible to move the slippers so that their centre does not coincide with that of the piston rod. If the surface referred to is turned in the lathe, the only way to alter the virtual centre of the slippers is to remove metal from their face. This is not such a big job when the slippers are faced with white metal, and in any case the distance that the centre can be shifted is very great in comparison with the amount of metal to be removed. It will occasionally happen that these slippers will shift while being turned up in the lathe, and have to be filed or scraped up. Where any metal has been removed, the slippers, unless tight to begin with, will have to be packed out from the crosshead. Where,

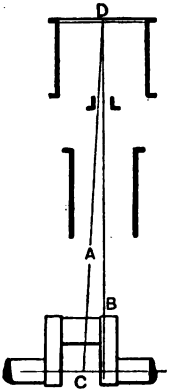

FIG. 19.

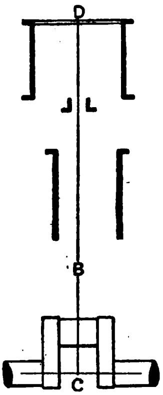

FIG. 20.

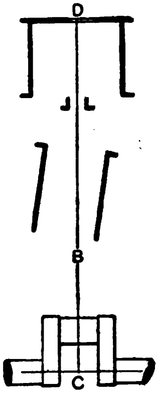

FIG. 21.

after adjustment, there is any play round the screws or studs holding the slippers in place, so as to allow any movement of the latter, steady pegs should be inserted to hold the slippers in their correct positions.

Fig. 21 illustrates an error corresponding to that shown in Fig. 12 in the previous series, and as in that case, the engine cannot work properly until this fault is removed. The conditions are even worse in the present instance, because in addition to giving a horizontal movement to the piston, the working of the crankpin is affected. In the plane of the figure the cylinder and crosshead guides must be co-axial or there will be trouble later. The error shown in Fig. 14 in the previous series was amenable to adjustment, but in the plane of the series now under notice such an error, if occurring, must be eliminated before the engine can work properly. Fig. 16 in the previous series shows an error that will exist in both planes, and there is nothing to add to the remarks previously made.

The instances of errors in alignment given and discussed do not by any means exhaust those possible, but similar reasoning should be applied in all cases. There are instances in which the movement of the engine is hampered by other external parts of the engine quite independent of the "piston line," and the erector should carefully consider every possible complication involved before he moves anything. It is the power of estimating the effect produced upon the subsequent erection of the engine and its future running by any departure from mathematical exactness, that makes the difference between a first-class erector and one of moderate ability.

CHAPTER XI

ADJUSTMENT OF CONNECTING ROD

One of the jobs involved in getting the piston line ready for erection is the fitting up of the connecting rod. In high-speed engine practice there are two designs of connecting rod. The one generally used for the smaller sizes of engine has the crosshead pin fixed in the connecting-rod jaws. In this case the crosshead is forged solid with the piston rod, and the brasses are carried in the crosshead. In the larger sizes of engine the crosshead is separate from the piston rod, being usually secured thereto by means of a cone and shoulder seating. For this purpose the crosshead is bored out and the rod passed through it and secured by means of a nut on the other side. In the latter case there are two crosshead pins, and the brasses are carried one on either side of the connecting rod. The bottom brass has to be bedded to the bottom of the connecting rod, and in doing this care should be taken that the tongue fits tightly into the recess provided for it, to prevent any movement of the brass on the rod. Pegs have to be fitted under the bolt-heads to prevent their turning when screwing up or unscrewing the nuts, and the proper recesses have to be cut in the caps. If the connecting rod carries the crosshead brasses, similar work will have to be done on them. The brasses then will have to be put together and bored out. The crosshead slippers require to be properly bedded to the crosshead, and if the latter is separate from the rod it should be fitted into position and screwed up hard, since the slippers should be turned up in their place. If the type of rod used has the crosshead forged solid with it, the brasses must be carefully bedded into the crosshead and pulled up into position in the machine.

After these parts have come into the erecting shop, the methods of procedure vary not only in different works, but in different sizes of engine in the same works, and also owing to comparatively slight differences in design the various methods adopted require that the jobs shall be tackled in different order. For instance, where there is a possibility of a connecting rod having to be canted over by " throwing " the brasses, as it is often termed, to suit any lack of alignment between the crosshead guides or cylinder and the crankpin, it is useless to spend time that may be wasted in swinging the piston and connecting rods so that they are exactly in line. In decent high-speed engine work this latter qualification should be insisted upon, and it is often convenient to do this before the crosshead goes into place.

In a large works there is often a bench and space devoted almost exclusively to the fitting up of the rods, and a squad of men always kept on this job. In one erecting shop the method used to get linability between the two rods was to place the piston rod upon trestles and run a steel wire down its side and scrape the crosshead brass until the connecting rod was parallel with this line. The arrangement adopted is shown in Fig. 22, which is a plan view. The piston rod rests upon two trestles, one placed at each end of it. On the rod at X and Y are fixed two V-clips into which are screwed wrought-iron holders. The clip at X is so arranged that its arm carries one end of the wire, and holds it firmly so that it will stand the strain of being pulled taut. The wire at the other end passes over a pulley, and sustains the weight required to put the necessary strain upon the wire. On the arm B attached to the clip Y there is a mark cut in such a position that when the wire passes directly over it, the line is exactly parallel with the piston rod. The connecting rod was held, raised, or lowered by means of a hand jib over it. Now, a heavy rod will keep pretty steady when being fitted up upon good stiff trestles, but this method was specially arranged to allow for any movement of the rod or trestle. A small movement of the wire along the periphery of the pulley will again bring the line over the mark B before any measurements are taken. Since the arms A and B are fixed to the piston rod, any possible slight movement of the latter will not affect their truth of position. A centre line E F is scribed down the centre of the connecting rod, and the rods are truly swung when dimension C coincides with D, while the line passes correctly over the arm B. As there will be a certain amount of play between the outsides of the crosshead brasses and the insides of the connecting-rod jaw, neither C nor D can be depended upon to remain constant; but these dimensions should be identical before the job is passed as correct. The final adjustment of the brasses should also be made here, and the bed of the brasses upon the pin must be a first-class job. It is a good thing to have liners in between the two halves of the brass, if only for convenience in erection.

In swinging the rod to the line, what will subsequently be the top brass should be tackled first, and to make sure that the back of this brass is up against the crosshead, and that its working surface is hard up against the crosshead pin, all liners should be taken out, when the bottom brass will simply act as a clip to pull the pin home into the top brass. Should the dimensions C and D not be identical, the crown of the top brass must be scraped until this result is obtained. Assuming that the distance between the points E and F where the measurements are taken is five times the width of the brass, it is then evident that an amount equal to one-fifth of the difference between the readings C and D requires to be scraped out from one side of the crown of the top crosshead brass. On the brass being taken out, a small area of metal should be scraped out to a little less than the depth required, gauged by inserting feelers under a straightedge placed on edge along the crown. The brass is then scraped down until this point bears on the pin, no metal at all being removed from the extreme opposite edge of the brass. On being put back it will be found that the rod is about right. It is much better to measure the amount of metal to be removed in thousandths of an inch, than to specify it loosely as a " light scraping " or a " good scraping." Such

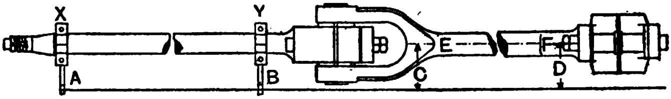

FIG. 22.

liners as are required will then be put back and the other brass carefully bedded down, its edges being filed down, if required, until its crown beds all over the pin. As with the main bearings, so with the crosshead, the initial stress on the bolts should be at least equal to the normal working stress that will come upon them, and the adjustment of the brasses required should be made with the nuts hammered hard home.

With regard to the amount of clearance to be left between the pin and the crosshead brasses, this should be cut down to the lowest limit to prevent " knock " at high speeds, and to preserve the pin from the destructive hammering action produced where there is any play in the brasses. An old method with marine engines was to adjust the crosshead bearing so that when the nuts were hammered hard home the rod when hanging freely from the crosshead would maintain itself at an angle of from 8° to 10° out of the vertical. It is good practice with large engines to mark the position in which the nuts have been set, so that they can be pulled up to the same position again without hesitation should they have been slacked back for any purpose. The crosshead slippers are often bedded to the guides when the former are separate from the crosshead, especially in the smaller engines. In any case it is necessary in the first instance to get them to come well down on the centre before proceeding with their erection. In larger engines it is often economical to bed the slippers down when the guides are vertical, so that a crane can be used for raising, lowering and rubbing them on the guides.

Owing to the comparatively greater working space available within the standards of the largest engines, jobs can be economically carried out at a stage of erection that would be both inconvenient and costly if tackled in the smaller sizes. In order to make a really good job of the piston line, the surfaces of the two slippers should be concentric, and to maintain this the steady pins or other means of locating them on the crosshead should be most accurately fitted. It is often found that when they come round to the engine they are slightly on the twist with one another, and also that their surfaces are not always parallel with the piston rod. The effect of this is to throw the piston rod out of the centre of the cylinder. As there are several thousandths of an inch clearance between the idle slipper and the crosshead, it is the practice of one firm always to pack this guide out temporarily until the crosshead is tight in the guides, and the slippers are thus bedded in, the packing being subsequently adjusted for the working clearance. This makes a good job.

Let the piston rod, without the piston being in place, be put in the cylinder, the crosshead with the slippers screwed up being between the guides, and the connecting rod coupled up to the crosshead and crankpin. For perfect running the requirements now are that with the working slipper resting upon its guide, the engine can be turned from the top of its stroke to the bottom without the axis of the piston deviating from that of the bore of the cylinder. At the same time a clearance must be maintained between the bottom end brasses and the crank-webs on the one hand, and between the crosshead brasses and the connecting-rod jaws on the other hand. With regard to these clearances, it should be made absolutely certain that the sides of these brasses are not bearing upon any portions of the radii where they exist at the ends of the pins, this being a fruitful cause of heating.

Now, the bottom end brass has not yet been adjusted, and the first operation is to ensure that when the rod is linable its top crankpin brass bears right across the crown. Take out the bolts and let the foot of the rod rest upon the back of the top brass. This will ensure the latter coming down all along the pin, and it can be ascertained, either by paper or feelers, whether the foot of the rod is bearing all over its surface on the brass. It is essential that this be so, and if there is any opening between the two, the metal must be removed as required from the working surface of the brass, and not from its back. Suppose that there is an opening under one side of the connecting-rod foot of 0.006in., and that the width of the brass where it bears on the pin is double that of the connecting-rod foot, it is evident that 0.012in. requires removing from one side of the brass, tapering to nothing at the other side. This can be carried out as described with the crosshead brasses.

CHAPTER XII

CRANKPIN ERRORS

THERE is another class of error to be met with in the piston line, and that is lack of truth in the crankpin. In the crankpins of high-speed engines this error is not so frequently of serious proportions, owing to the stiffness of the stereotyped designs, but it is by no means uncommon in cases where the crankpins are overhung. Owing to the lack of proper stays in the lathe, or to their inaccuracy when fixed, or to the wearing out of truth of the centres of the shaft, crankpins may be axially out of parallel with the shaft. In the case of shrunk-in pins, machine-tool errors will produce the same effect. Fig. 23 shows an error to a very exaggerated degree, and one which makes cool running difficult. Even if the lack of alignment amounts to only a few thousandths of an inch, reliable, cool running is difficult to obtain, and especially is this the case where the bearing surfaces are proportionately small, and the calculated bearing surface per square inch is high.

Referring again to Fig. 23, supposing that the erector adopted the method of bedding the brasses to the crankpin as given above, the result would be the state of affairs shown greatly exaggerated in Fig. 24. As long as the crankpin remained in the position shown, the top half of the brass would bed all along the pin. Should, however, the crank be turned through 180°, the top brass would touch only at one end of the pin, as in Fig. 25, the error in alignment being to all intents and purposes doubled. From this point of view only it would have been better to leave the brass on its wearing surface parallel with the axis of the shaft, in which case the maximum error would be equally divided, so that one half only would be apparent at top and bottom stroke respectively. As far as this aspect of the error is concerned, the running results depend entirely upon the design of the big end, and the conditions under which the brass is held.

Referring to Fig. 26, it will be seen that in the type of brass shown the pressure transmitted through the rod is applied at a point D which lies between the two ends A, B of the rubbing surface of the brass. The result is a tendency for the top brass to leave the rod at C and lie along the crankpin. This will take place provided that the brass is not rigidly held in the rod and is not prevented from taking this position by the lower half of the brass coming into contact with the edges of the upper one. An erector once secured cool running with a troublesome crankpin on an engine put down by his firm, by inserting a strip of thin packing in the centre of the brass between the latter and the rod, and by adopting the same device with reference to the bottom brass and the cap, as shown in Fig. 27. He then reduced the edges of both brasses so as to clear one another, the brass rocking on the point K as shown in the

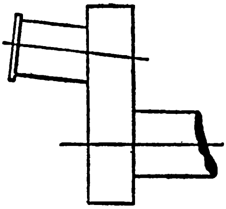

FIG. 23.

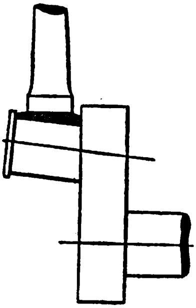

FIG. 24.

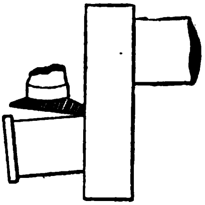

FIG. 25.

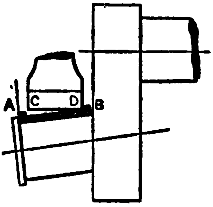

FIG. 26.

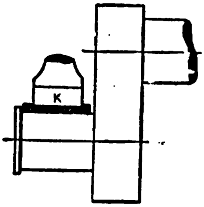

FIG. 27.

case of the upper brass. The erector in question having studied the geometry of the subject, grasped the problem, and gained no little kudos for getting the big end to run cool where several good men had failed. The device was discovered by the local engineer having some weeks afterwards taken out the brasses, and not having noticed the packing, failed to put it back with the brasses. This led to a recurrence of the old trouble. In previous sketches the effect of a certain error in alignment has been shown in the crankpin on top and bottom stroke, but a further distortion in the working of the piston line at middle stroke is shown in Fig. 28. This figure, which is a plan view, gives diagrammatically and with exaggeration the twist that will be given to the connecting rod in mid-stroke by a crankpin axially out of truth in the direction just discussed.

It is thus evident that the provision made for the rocking of the brass as in Fig. 27 does not completely meet the case, but that either the piston and connecting rod must twist alternatively to the right and to the left at each stroke, or that the brass must swivel in the rod. Now, in the case of an engine with circular crosshead guides, there is nothing to prevent the crosshead from so twisting; but with flat guides this is impossible, and unless there is sufficient play between the brass and the connecting rod at one or both ends of the latter, cool running with full bearing surface cannot be obtained. The whole of the remarks made with reference to the top brass are equally applicable to the bottom brass, and if the two halves of the brass are bedded down on the pin and fit snugly together, the tendency is to produce an actual bending of the rod at top and bottom of the stroke, in addition to twisting it in the two middle positions.

During the experience of the writer with a firm building large central-station engines, of a type with overhung crankpins and the dynamo placed centrally on the shaft, he never saw a pair of engines of more than 800kw. capacity go out of the works with the error in the alignment of the crankpins amounting to less than 0.005in. in their length. The practice of the firm was to scrape out the brasses until they were slightly taper in bore, as in Fig. 29, so that there was no tendency to cross-corner the brasses on the pin. Only the liberal bearing areas and forced lubrication with high-viscosity oil kept these bottom ends at a workable temperature. It was further found advisable with these engines to fit a large cold-water circulating coil in the working oil tanks fitted below the engine. Where the crankpin is out of alignment with the shaft there is generally an axial movement of the rod along the pin, provided that there is any end clearance. This is obviously so, since the steam pressure, not being exactly at right angles to the surface of the pin, produces a resultant parallel with the pin's axis. An examination of the previous diagrams makes it evident that this resultant will be alternately to the right and to the left as the engine is working. Even where the end clearance of the big end brasses is small, the particular distortion of the crankpin under discussion will often produce a very audible knock.

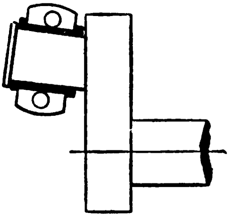

FIG. 28.

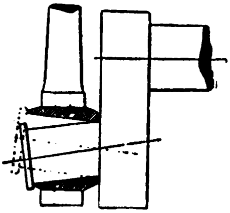

FIG. 29.

The slight knock that is heard too frequently on the big ends of horizontal mill engines is often due to this sliding of the brass along the pin, and striking alternately on the crank and the pin shoulder during each revolution, and this in its turn is due to lack of alignment in one form or another. While this class of engine will often work under such conditions, in a high-speed engine these errors spell trouble ahead.

It should be noted that while the fact that the stress transmitted through the piston is not perpendicular to the crankpin will always produce a tendency to axial movement in the bottom end brasses of a double-acting engine, the matter is not nearly so serious if the axis of the pin is parallel with that of the shaft. In Fig. 30, which is an exaggerated diagram of a shaft low at one end, it will be noted that the angle between the crankpin and the axis of the connecting rod remains constant throughout a revolution, whereas in the previous cases this angularity varied in both magnitude and sense, thus tending to produce dangerous racking and twisting stresses. Several instances have been pointed out in which errors of alignment, which would not have been permissible with flat crosshead guides, are innocuous in an engine having circular guides. The following is an instance in point. In Fig. 31, which is a plan view, the back of the crosshead guide is not parallel with the crankshaft. It is evident that there will be a resultant in the direction shown by the horizontal arrow, the effect of which will depend upon the design of the crosshead, and the means taken to constrain it to move in its appointed path, and also upon the actual position of the crosshead pin. Should, however, the guides be circular, the crosshead will automatically adjust itself to the position of correct working alignment as in Fig. 32.

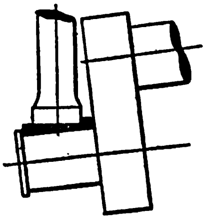

FIG. 30.

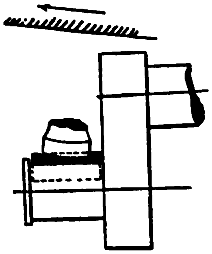

FIG. 31.

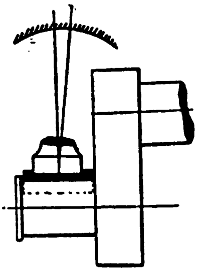

FIG. 32.

There are two other crankpin errors which perhaps deserve passing mention, one of them being lack of uniformity in the diameter of the pin measured at various points along its axis. One end of the pin may be slightly larger in diameter than the other, the pin thus being slightly conical. This is an uncommon error in a new engine, as its presence is so easily discovered by the turner when the shaft is in the lathe. It is, however, not unknown in engines that have been running for some time; but if the erector has studied the subject on the lines laid down he will have no difficulty in dealing with the matter. The second error is one that is invariably met with in an engine that has been at work long enough for any appreciable wear to have taken place, and that is the tendency for the crankpin of a double-acting engine to wear more or less elliptical in transverse section. The actual form of the section will depend upon the design of the engine and the relation of the steam distribution to the inertia of the reciprocating parts, but more wear will generally take place on one side than on another. In Fig. 33 the crankpin starts from A on its outward stroke, the direction of the steam pressure on the piston being shown by the horizontal arrow. The shaded portion of the pin at A takes the full working pressure at the commencement of the out-stroke, and it will be noticed that the pin itself will have turned through a complete half revolution by the time that it has reached the commencement of the in-stroke. Thus at the commencement of the in-stroke the pressure is upon the same side of the pin as at the corresponding period of the out-stroke. The point to be noted is that whereas the brasses must be bedded to the flat side of the oval pin, the relative adjustment of the two halves of the brass must be such as to leave a space between them for the larger diameter of the pin. This is clearly shown in Fig. 34.

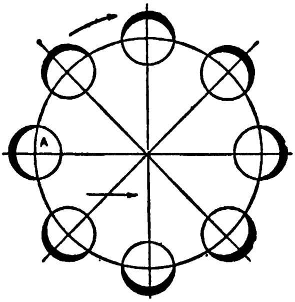

FIG. 33.

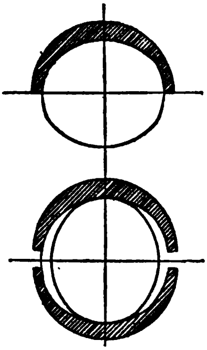

FIG. 34.

The writer must not be understood to assert that there should be no end movement in the various bearings of a steam engine. On the contrary, such a movement has a very distinct advantage, both in the interests of cool running and in those of the long life of the wearing parts, and more especially so with the harder bearing metals and bronzes. The reason for this is that neither are the wearing surfaces of the bearing metals mathematically smooth when the engine is first started up, nor are these metals of such uniform texture as to wear equally all over their working surfaces. Thus, the hard places on one metal come opposite softer places on the other metal in contact with it. A series of grooves will be worn in the direction of the relative movement of the two surfaces. The same effect is produced by particles of grit and other foreign substances becoming embedded in the softer metal, and thus cutting grooves in the harder. The tendency is towards a state of affairs similar to that shown in Fig. 35. If the two surfaces are constrained to move one over the other in accordance with the arrows, the ridges will come out of the corresponding furrows, and the excrescences on both surfaces will be worn away. The above is not to say that the main working portions of the engine should be intentionally left out of true alignment in order to obtain this end play. The proper, and the best, method is to take the greatest pains to make the alignment as true as possible, and to leave a little side play where necessary. However great be the care taken in erection, a constant absolute balance of the side forces about the bearings is impossible of attainment, and however small such unbalanced varying forces may be they will be larger than is necessary to obtain the desired axial movement.

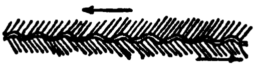

FIG. 35.

CHAPTER XIII

PISTONS AND RINGS

THE piston rings have usually been fitted to the piston at the piston bench, but in some works this job is carried out under the supervision of the man who has charge of the erection of the engine. The method of procedure depends upon the design of ring used, and there are innumerable designs of patented piston rings on the market, each of which has its advantages and disadvantages. If the ordinary Ramsbottom ring is used, no piston junk ring is required, the rings being simply sprung into recesses turned in the periphery of the piston.

As the pressure required to make a steam-tight joint between the piston ring and the cylinder walls is comparatively very small, probably only 3 to 4lb. per sq. in., modern Ramsbottom rings are very light, and require judicious handling when being fitted into the groove. If the rings are made any stiffer than is required for the above purpose, the additional radial pressure only causes unnecessary wear of both the cylinder and the rings. A great part in the success in the working of a Ramsbottom ring depends upon its original fit in the groove. If this fit is a good one, the ring will not only maintain a good steam-tight joint, but will remain staunch over a long period of time. On the other hand, if there is the slightest play between the ring and the groove, when the engine is started a hammering action is set up and the amount of play rapidly increases. An examination of badly-fitted rings that have been taken out of an engine that has been running for some little time is very instructive. Sometimes a ring will come out of the groove in the form of a few handfuls of lozenge-shaped pieces with all the corners nicely rounded off, a proof of the severe battering to which they have been subjected by the reversals of the piston. In a high-speed engine running at a speed of 500revs. per min.

for ten hours a day, a slack piston ring will be struck over four million blows in a week. Where a ring is a proper fit to commence with. the force of the blow is practically zero. Piston rings of the Ramsbottom type are usually turned of such a width that they just fail to enter the groove turned for their reception in the piston, and are finished to correct size with a flat scraper. The rings are tried in the grooves several times during the process of fitting, and it not infrequently happens that they become wedged in, and can only be extracted with difficulty. It is in getting the jammed ring out of the groove that so many breakages occur, and if such a ring becomes really fast the greatest care must be used in extracting it. The usual process of fitting is first to let the back of the ring into the groove as in Fig. 36; but the sides of the groove must be dead parallel if the same fit is to be obtained when the ring is turned round into its working position. Thus the first thing to be ascertained is whether the sides of the groove are truly parallel, and it is not an uncommon thing to find that they require a little adjustment. Accuracy in this respect can be tested by means of a small gauge similar to that shown in Fig. 37. The steel from which this gauge is made should not be less than ⅛in., so that a little red-lead marking can be used when testing the groove.

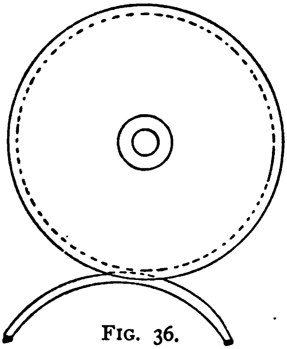

FIG. 36.

Having ascertained the maximum width of the groove, the ring should be carefully gauged so as to make sure that it will not be slack when the sides of the former are trued up, should any deviation from the parallel be found to exist. There should be plenty of stock in the ring to allow for fitting. It is obvious that unless the sides of the ring are truly parallel any variation in the internal diameter of the cylinder throughout its length will affect the staunchness of the piston-ring joint. The outward radial movement of the ring as the latter follows the variations of the cylinder bore, or its general increase in diameter due to wear, will cause an opening between the piston and the ring if the sides of the piston-ring groove are out of parallel as in Fig. 38, or even if the ring is a perfect fit when closed in as in Fig. 39.

Another essential is that each side of the groove all around the piston lies wholly in one plane; otherwise it is evident that it will be impossible for a parallel ring to make a snug fit in the groove. In Fig. 40, in which, of course, the error is greatly exaggerated, the ring will touch the top of the groove at A and the bottom of the groove at B, and will consequently feel tight to the touch. It will, however, be open at C and D. For this reason it is better to avoid, wherever possible, touching the grooves after the piston has left the lathe; but should such a course be necessary, it is important that only one side of the groove be worked upon at a time, and then the other side of the groove can be worked to as a guide. When the groove is perfectly true and parallel the job of fitting the ring can be proceeded with. In Fig. 36 was shown the preliminary method of fitting in the ring, and providing that the sides of the ring itself are quite parallel, the necessary stock should be removed from only one side, for the same reason as applied in the case of the grooves. After the ring has been fitted in this method it can be turned round and tried into the groove in its proper working position. It is during this process that so many breakages of piston rings occur.

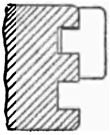
FIG. 37.

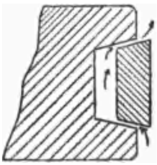
FIG. 38.

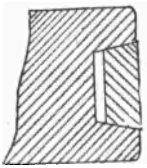
FIG. 39.

Referring to Fig. 41, it will be seen that should the ring become wedged in the groove at the point X, it will be difficult to apply pressure to remove it without the necessary force being used at a distance from the point X approximating to the internal radius of the ring. Thus the ring becomes for all practical purposes a cantilever, and the maximum bending stress is at X. It is obvious that in attempting to remove a ring that has become fast in the groove, the outward pressure should be applied as closely to the point X as possible. To effect this the tool used to prise the ring out should be as thin as possible. The effect of a tool of large sectional area in increasing the dangerous sectional leverage mentioned above is clearly shown in Fig. 42 at the point M, whilst this leverage is much decreased by using a thin tool which can be moved round the piston beneath the ring as far as N. A useful tool for the above purpose is a piece of thin sheet metal bent as in Fig. 43.

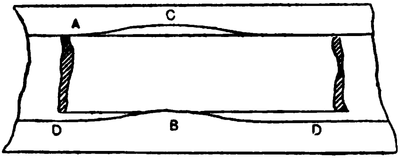

FIG. 40.

The ordinary Ramsbottom ring has several disadvantages. In the first place there are no means of taking up the wear due to the hammer action previously referred to; and, further, since to increase the durability of the ring under working conditions a fairly large radial depth is required, the desired depth for this purpose often increases the stiffness of the ring to such an extent that it cannot be well sprung over the piston. When this state of things exists, the only way of getting over the difficulty is to fit a junk ring, which also answers the first objection in making the groove adjustable for wear. This, how-

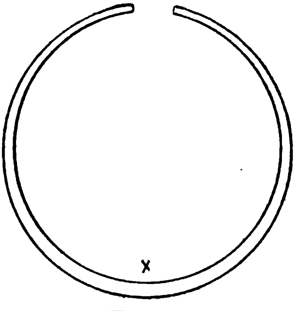

FIG. 41.

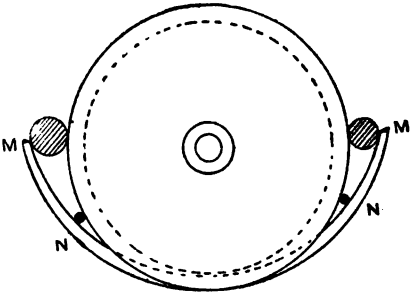

FIG. 42.

ever, is a departure from the simplicity of the Ramsbottom ring in its elementary form. Another objection is that the light Ramsbottom ring as usually made does not give a uniform radial pressure round the inner circumference of the cylinder; and, further, when the ring becomes slack the steam pressure gets behind it, and under certain conditions causes a very rapid wearing of both the ring and the cylinder. It is in order to overcome these objections that springs of various designs are used to supplement in part the outward pressure of the ring itself. In one design two rings are used as in Fig. 44, with a spring between them to force them apart against the piston. This not only tends to take up any wear in the groove, but the outward resultant tends to maintain a steam-tight joint on the cylinder walls.

The majority of rings of any size are now fitted with a tongue-piece at the joint, and in the best practice these are so arranged that the ring is only allowed to expand through a few thousandths of an inch in its diameter. The ring then becomes, through the restraining action of the tongue, to all intents and purposes solid. Whatever be the design of ring used, or in whatever part of the works it be fitted to the piston, the erector should always try each ring into its own cylinder by itself, so as to make sure that it will pass freely from one end of the cylinder to the other. It should also be noted that whatever be the variation in the bore of the cylinder from one end to the other, the piston ring will always open and close at the joint over three times the amount during a double stroke, owing to the fact that the circumference of the ring is 3.1416 times its diameter.

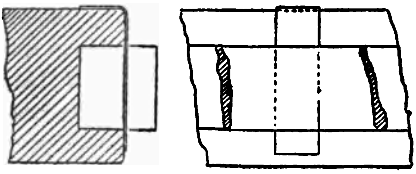

FIG. 43.

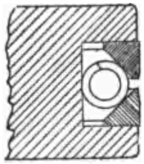

FIG. 44.

If the importance of having all nuts, set-screws, and other loose parts securely fixed and locked can be of greater importance in one part of a steam engine than another, it will be in the cylinder. Here the greatest precautions must be taken against the remotest possibility of anything coming adrift whilst the engine is working, as the consequences might be disastrous. On the other hand, junk ring studs have been known to break after starting up, owing to a misguided enthusiasm in pulling them up too tightly and stressing them close up to their breaking limit. The end clearances in the cylinder of a modern steam engine are so small that there is no room for anything beyond the steam. After the rings have been satisfactorily tried in the cylinder, both they and the piston can be put in place. As the portion of the piston rod at its smallest diameter where it passes through the piston is subjected to very severe working stresses, and its sectional area is proportioned with a view to the fact that the stress will not change in direction during one revolution of the engine, it is necessary to hammer up the piston-rod nut until the initial stress in the rod is at least equal to the working stress that will come upon it. If this is not done there is always a danger of the piston becoming loose. In large engines it is often necessary to put an additional stress upon the spanner that is being used for this purpose whilst it is being struck with the hammer. The nut must also be securely locked.

It might be thought needless to draw attention to the fact that all tools and the like should be removed from the cylinder before the cover is put on; but in the personal experience of the writer he has known of four cases where breakages have occurred from this cause. In one case the low-pressure cylinder cover of a marine engine was broken by a large hammer which had been left in the cylinder. The natural embarrassment of the forgetful erector at the sudden reappearance of his hammer through the cylinder cover might have been avoided by a last look round just before the covers were dropped into place. In another instance a forgotten centre punch became wedged in one of the openings of a grid-type slide valve and broke both the valve and its seating.

CHAPTER XIV

CYLINDER CLEARANCES

THE clearance between the piston at both top and bottom stroke and the respective cylinder covers must be carefully measured before the cylinders are finally closed up. The amount of this clearance varies with the class, size and design of the engine, and is a compromise between conflicting requirements. In the interests of steam economy these clearances should be as small as possible. On the other hand, practical considerations, such as the possible presence of water in the cylinder and the normal wear of the brasses, demand a certain minimum space between the piston and the ends of the cylinder when the former is at the extreme ends of its stroke. In a modern vertical high-speed engine the cylinder is self-draining, being so arranged that any water present with the steam will flow by gravity into the exhaust ports. The same object is obtained in horizontal Corliss engines when the exhaust valves are placed in the bottom of the cylinder. A high-speed engine of the type under discussion will safely work with a smaller clearance in the end of the cylinder than would be advisable with the average steam winch, where the work is intermittent and the quantity of water in the steam usually large, owing to the length of the steam pipes and their position. In a vertical steam engine the clearance is usually made greater at the bottom, since the wear of the crosshead, bottom-end and crankshaft bearings tends to bring the piston lower in the cylinder, and thus decrease the bottom clearance. An old rule in marine-engine practice expresses the requisite amount of bottom clearance solely in terms of the permissible wear in each of the three brasses mentioned.

The use of white metal in the engine bearings has also a bearing on the question, and a case recently occurred in a high-speed engine where the bottom-end bearing became hot and the white metal ran out, thus allowing the piston to strike the bottom of the cylinder, which it cracked. Another consideration which reaches its greatest importance in tandem-cylindered engines is the expansion of the piston rod owing to its increase in temperature due to contact with the steam.

It does not always follow that the wear of the connecting-rod brasses will shorten the centres of the connecting rod by an equal amount. In the horizontal Corliss engine it is generally arranged by the best makers that while the taking up of the wear of the big end brasses will shorten the rod, the same operation at the small end will lengthen the rod. Assume in Fig. 45 that X and Y are the connecting-rod brasses of the small and big ends respectively. It is evident that if the half brasses A and D remain stationary, and that, in order to take up wear, the half brasses B and C are adjusted towards the crosshead and crankpins respectively, then the centres K will be increased. On the other hand, by making B and C fixed, and adjusting A and D, the virtual centres K will be shortened. Should, however, B and D be fixed, and A and C made adjustable, no amount of wear will affect the length of the rod, provided that the wear is the same at both ends. Unfortunately for this object, there is, under normal conditions, generally more wear on the crankpin brasses than obtains with the crosshead, so that the influence of the wear of the connecting-rod brasses on the cylinder clearance is only mitigated, and not counteracted entirely, by the above practice. It, however, allows the clearances to be cut down finer than would be otherwise possible.

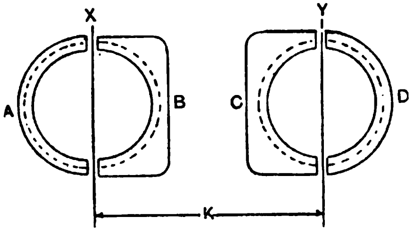

FIG. 45.

Where the clearances are to be cut very fine it is better to machine both the surfaces of the piston and the insides of the cylinder covers to templets, so as to ensure the clearance being uniform over the whole surface. In fact, in the best high-speed engine practice this is always done, the machined surfaces being afterwards polished, as this considerably decreases the amount of surface on which condensation can take place. Referring to Fig. 46, the waved line A B may be taken to represent diagrammatically the amount of surface lineally on a given length in a rough casting, whereas when the same surface is machined and polished it will approximate in one dimension to a straight line of equal over-all length C D. Were the line A B stretched out it would give 50 per cent. increased over-all length E F. Therefore, the ratio of the two surfaces, machined and rough respectively, exposed to the condensation of steam, would, on the above assumptions, be as the square on A B is to the square on E F. Whatever be the amount of clearance allowed at the top and the bottom of the stroke, it must be clearly marked on the crosshead guides, so that the engineer running the plant can see when the wear of the brasses has brought the piston too close to the lower end of the cylinder at the bottom of the stroke.

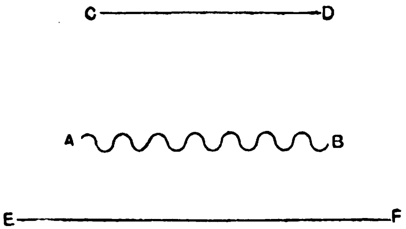

FIG. 46.

The only way of finding out what mechanical clearance there is in the cylinder is to bring the piston into actual contact with the top and bottom cylinder covers alternately. In order to let the piston rest upon the bottom of the cylinder, the rod must be taken off the crankpin and the position visibly recorded for future reference. The usual practice is to cut a mark upon a convenient portion of the crosshead slipper with a sharp chisel near the guide, and then, when the crosshead is at its lowest possible position as above, to cut another mark exactly opposite it on the guide in such a manner that the one line cut on the guide is a continuation of the one cut on the slipper. The piston is then lifted up until it touches the inside of the top cover, and the crosshead guide is marked as before. In order to allow this lifting operation to be easily carried out, several firms in their larger engines put a larger eyebolt in the cylinder cover than in the piston-rod end. It is thus possible to pass a long eyebolt through the hole in the cylinder cover and screw the same into the end of the rod when the piston is lying at the bottom of the cylinder. Thus, in order to mark upon the crosshead guide the position occupied by the crosshead when all top clearance is taken up and the piston and cylinder cover are in actual contact, a rope sling may be passed through the eye of the eyebolt and the piston lifted by means of the shop crane.

A rope sling rather than a chain is specified, because there is sufficient stretch in a rope, if of reasonable length, to allow the erector to bring the piston up to the cylinder cover without running any risk of breaking or straining anything. On the other hand, owing to the rigidity of a chain, the greatest skill and care on the part of both the erector and the crane driver are essential to prevent over-lifting. When the piston is in the position stated, the corresponding chisel mark may be cut upon the crosshead guide opposite to the datum mark on the crosshead. There will now be two marks on the guide, and the distance between them is equal to the length of the total possible movement of the piston between the covers. The crankpin brasses can now be put back, and the bottom end coupled up. The crank should now be turned alternately to the top and bottom centres, and the datum mark on the crosshead projected in each case on to the guide. There will now be four marks on the crosshead guide as in Fig. 47, the distance between B and C being the length of the working stroke of the engine. The distance between A and B gives the actual cylinder clearance at the top of the stroke, and the corresponding distance between C and D gives the clearance at the bottom of the stroke. As the brasses wear, the mark O on the crosshead will tend, on the bottom stroke, to approach the mark D, but there will be no danger of the piston striking the bottom of the cylinder until the brasses have worn sufficiently to allow the mark O practically to coincide with D when the crank is on the bottom centre.

In the best practice the joints between the cylinder and their covers are ground, and no soft packing is used. In this class of joint the width of the surfaces in contact at the joint is very small compared with the width of surface required to make a staunch joint with soft packing. The surfaces forming the joint are often only $\frac{3}{8}$in. wide, and after being scraped up are ground together with emery powder and oil. In cases where thick, soft packing is used, an allowance for its thickness must be made in estimating the actual cylinder clearance.

Before closing the cylinders for good, the engine should be slowly barred round, and the erector should satisfy himself that the edge of the top piston ring overruns the point where the counterbore commences, but that the whole of the ring does not pass this point, otherwise the ring will move outwards radially into the counterbore every stroke of the engine. The erector should further make sure that there is no possibility of the ring getting into the steam ports. The same, of course, applies to the bottom ring at the lower end of the stroke. Ramsbottom rings are usually pinned in such a manner that they will not work round in the groove, and the joint in the ring should be arranged in such a manner that the two ends of the ring cannot spring out into any recess in the cylinder barrel. It is by no means an unknown occurrence for the ends of a ring to get caught in the opening arranged for use when indicating the engine. In some engines it has been found that exceptionally weird indicator diagrams have been due to the piston overrunning, wholly or partially, the opening through the indicator boss. Should these holes not come clear beyond the piston when the latter is in its extreme positions, a way must be chipped in the cylinder walls to allow for the free passage of the steam. In conclusion, the cylinder walls should be well greased before the covers are finally put on, since, due to financial or other causes, a completed engine may stand for many weeks in the works before being dispatched to its destination.

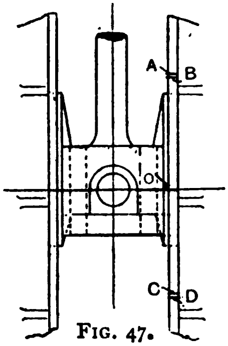

FIG. 47.

CHAPTER XV

PISTON-ROD PACKINGS AND VALVE SETTING

MODERN high-speed engines are fitted with metallic packing round the piston rods. Some years ago there was apparently supposed to be some esoteric knowledge required for the designing and fitting of metallic piston-rod packing, and thus in the majority of cases the packing was supplied and fixed by a few firms with which it was a speciality. The wonderful improvement in working conditions brought about by metallic packings could have been seen by any observant engineer from the railway platforms of British railways. The grooved, scored, and fluted piston rods in the locomotives fitted with old-fashioned stuffing-boxes, packed with soft packing, were very noticeable compared with the modern locomotives where metallic packings were used. Hot rods and leaky stuffing-boxes were a frequent occurrence, whereas a floating packing will work satisfactorily where perfect alignment does not obtain. A good, simple, straightforward packing can be made and fitted by engine builders themselves, and it is now essential that an up-to-date erector be able to fit and install them. The first essential to the successful working of a metallic packing is a truly round and parallel and well-finished rod, and for this reason most consulting engineers specify that piston rods must be finished by grinding, and not merely made to look nice by being finished with a file and emery cloth in a lathe. The second essential is that the white metal packing rings be bedded to the rods, and the same care must be exercised with all surfaces that work in contact with one another, including those by which the joint is made at both ends of the stuffing-box, and upon which the movement takes place should there be any lateral movement of the rod during the stroke. Several of the patented packings have the rings formed of white metal run into brass boxes, and the trouble with this form of packing is that the white metal is apt to come loose from the boxes. In order to prevent this the greatest care must be taken in running the white metal, and the interior of the box should always have been previously tinned. The result of the white metal coming loose is that the edges of the brass boxes bear hard upon the rod, and the latter wears unevenly as the result. In addition to the points mentioned above, the erector should take care that there is clearance between the two halves of each packing ring so as to allow for automatic adjustment for wear, and where two flat surfaces of the packing come together, as mentioned above, at least one of each pair of surfaces should be bedded on to a first-class surface plate before erection, as these parts are often found to be a little out of truth when they come to be erected, especially if the rings are light and easily distorted. Also, if the rings of white metal have not the protection of the brass boxes, their edges are easily barred by careless handling.

One great objection to soft fibrous packing is that it will retain grit which it picks up from the rod passing through it, and hold it embedded in its surface indefinitely, in much the same way that a lead lap holds emery, and this is one of the reasons why soft packing scores the rod. When first an engine is started up, the presence of a quantity of grit in the cylinder is unavoidable, especially where there is a considerable length of steam piping. There is a tendency for rust scale and sand to be loosened by the heat, moisture and vibration, and thus carried into the cylinder by the inflowing steam. An ideal anti-friction metal should not be soft enough to retain such foreign matter as may get between the working surfaces. One firm of engine builders who commenced to make their own piston-rod metallic packing fell into the error of making far too soft a mixture. The alloy contained too much lead and too little antimony and tin. The form of the edges of the packing which meet the entering rod has quite a little influence upon the amount of dirt that will get into the packing.

The same thing is noticeable in the case of the wiper gland, through which the rod passes as it enters the crank chamber.

The object of this gland may be said to be twofold—namely, to keep any drip from the piston-rod glands from entering the crank chamber, and also to prevent any oil from creeping up the rod. In the earlier designs of high-speed enclosed engines, a portion of the rod, which at the lower end of the stroke entered the crank chamber, returned into the cylinder during a part of the up-stroke, and, especially in the case of the low-pressure cylinder when exhausting into the condenser, drew up a considerable amount of oil. In some cases the quantity of oil getting in this way into the condenser amounted to gallons in a week. It was found that the efficiency of the gland in preventing undesirable matter from passing through it was largely influenced by the angle of the edge of the packing.

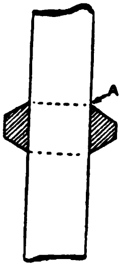

FIG. 48.

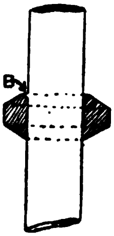

FIG. 49.

The angle of the packing ring at its edge as shown in Fig. 48 should be fairly acute, and its edge A should be a sharp one. In Fig. 49 is shown an exaggeration of the action of a rounded edge. It is very evident that any grit getting wedged into the angular space at B is likely to be carried forward and squeezed in between the rod and the packing. The erector should therefore, where this type of ring is used in the stuffing-boxes, exercise the greatest care to see that the knife-edge is maintained on the ring, and the same applies to the wiper gland. In a case which recently came under the notice of the writer the whole of six sets of packing rings had to be removed from a four-cylinder triple horizontal engine in a Lancashire cotton mill within three months after starting up. This was entirely due to the amount of foreign matter held in suspension in the feed water, which was carried along by the steam into the cylinders. In most stuffing-boxes fitted with metallic packing there is a drain cock provided for the purpose of getting rid of dirty and gritty water, and the erector who starts up a new engine should pay attention to this cock and thus save scoring the rod at the most critical period of an engine's life.

Piston valves in the small sizes of high-speed engines are usually made solid and without rings, as the wear upon the valves is very small, the valve practically floating in vertical engines. In the medium and larger sizes, rings are generally used, but in the best practice *split* rings have been abolished. Rings in a piston valve work under conditions somewhat different from those obtaining in the steam cylinder. In the former case the rings have to pass over steam ports, and split rings are often a source of danger, besides being unsatisfactory with superheated steam. The rings now used for this purpose are solid, and after years of running the amount of wear has been found to be negligible.

The actual position of the valve on its spindle with reference to the corresponding position of the piston in the cylinder is, of course, to be more closely determined than that of the piston itself, and for this reason it is made adjustable on the spindle. This adjustment is allowed for, either by double nuts on the spindle, or, better still, by means of a loose washer under the valve, which is turned up to the required thickness when the correct position of the valve on the spindle has been obtained.

The operation of setting the piston valves on a high-speed engine is a very simple one, although there is a tendency in certain quarters to claim that the operation is above the mental capacity of a mere erector. The simplest method is by means of a couple of staves, each of which requires to be planed up at least on one side and one edge. When prepared, one of these staves is laid against the side of the piston valve, and the four working edges of the valve reproduced upon the staff as in Fig. 50, the edge of the staff adjacent to the valve having been carefully trued up. The lines A, B, C, D in Fig. 50 are best described with a joiner's scriber used against a small tee-square. A lead pencil with a fine point can then be run along the scribed lines, thus making them easily visible. The spaces A B and C D should then be neatly hatched by drawing upon them inclined lines as in Fig. 51. The other staff, similar to the above, should then be placed within the valve-chest, and the positions of the ports reproduced upon it as in the case of the valve.

The object now is to place the two staves together in such a manner that their relative positions will correspond with the relative positions of the ports and valve at any desired period of the engine's stroke. The usual method of obtaining this result involves as a first step the placing of the piston at one end of its stroke. Now, at this particular period of a revolution of the engine, the movement of the piston is very small compared with the corresponding movement of the crank. Thus, the greatest accuracy in obtaining the positions of "dead centre" is secured by working from the position of the crank, and not from that of the piston or cross-head.

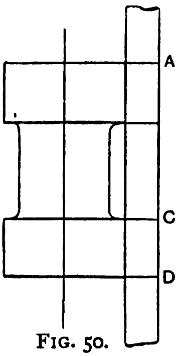

FIG. 50.

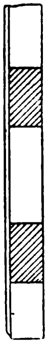

FIG. 51.

When the piston is nearing or leaving the end of its stroke, the piston valve is moving at a speed somewhere near its maximum, and in arranging the relative positions of piston and valve any error in placing the piston at its extreme end stroke will have a marked effect upon the valve setting. Thus, the method of setting the piston at the end of its stroke in a vertical engine is in its essentials as follows. The position need not necessarily be marked upon the bottom end or upon the crank, since as good, if not better, results may be obtained by using the fly-wheel for this purpose. Place the crosshead in a position a little below half-stroke, when the motion of the piston will be comparatively rapid compared with its mean lineal speed. Carefully mark the position of the crosshead by scribing a line on the edge of the slipper and extending it on to the crosshead guide as at O in Fig. 52. Take a fixed trammel, and with one of its points held in a fine centre-punched hole on the engine bed, or any other convenient portion of the engine framework, scribe with the other point the arc X upon the fly-wheel. Now turn the engine round until the obliquity of the connecting rod is on the other side of the centre line of the cylinder, the crank-pin leaving the position A and taking up a new position B, which latter position will be reached when the mark O on the edge of the slipper again coincides with the corresponding mark O on the edge of the guide. When this position has been exactly obtained, scribe upon the fly-wheel with the same trammel from the same position on the bedplate as before the arc Y. Bisect the portion of the circle X Y at Z. Now, when the point Z is brought under the point of the trammel, the piston is at the bottom of its stroke.

A similar method of procedure will locate the top centre. Now, one of the staves referred to above—namely, that upon which the working surfaces of the valve have been reproduced — can be placed upon the top of the valve, and the other staff representing the steam and exhaust ports can, after being cut to the required length, be placed upon the top of the valve chest, the edges of the two valves lying upon one another as in Fig. 53. Assume that the piston is turned to the top centre and the piston valve is one that has its steam edges on the outside. The lead of the valve being given, with the particulars supplied from the drawing-office, it is a simple matter so to adjust the valve that its steam edge is just below the upper edge of the steam port by the amount of the lead. The staves are then so adjusted in length that the same port and valve edges marked upon them occupy a similar relative position. If the engine be then slowly barred round, the respective

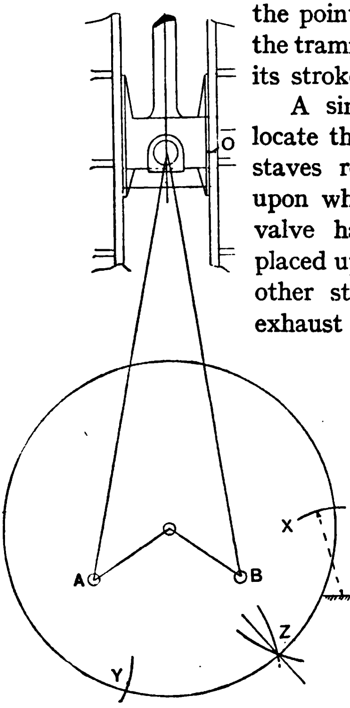

FIG. 52.

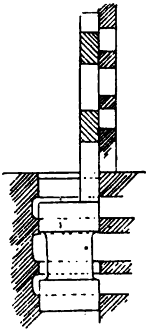

FIG. 53.

positions of valve and ports are faithfully reproduced by the movement of one staff upon the other throughout the cycle of operations during one double stroke. These can then be checked against the particulars supplied by the drawing-office. All that is required is that the erector should be supplied with the required position of the valve in the valve-chest at any given position of the stroke.

CHAPTER XVI

GENERAL REMARKS

It is often the practice when working upon the bearings and other parts of an engine to plug up the oil-holes with small pieces of cotton waste in order to prevent filings and other foreign matter getting into the oil passages, and thence into the bearings. It thus sometimes happens that these small plugs of waste are overlooked when closing up the bearings, and the supply of oil is thus blocked. The general result is a hot bearing. Now, cotton waste is in itself unclean, and owing to the manner in which it is handled and packed in the mill the cheaper sorts of waste are not only dirty but gritty. Such waste when used for wiping out a bearing will often leave behind it more objectionable matter than it removes. Many engineering firms buy cotton waste on the basis of price only, simply placing their orders with the firm that quotes the lowest price per pound, and the more dirt and grit carried in the waste the heavier it will weigh. Another reason why cotton waste is unsuitable for high-class engine work is that portions of the cotton adhere to machined surfaces when they are being wiped. A far more cleanly and efficient material for wiping engine parts is the sponge cloth woven from silk waste. These cloths are washable, and will wear for a considerable time; and being strong, will stand a lot of hard usage. For a final wipe round the brass of an important bearing before closing it up nothing beats the hand of the erector, since any gritty substance can be felt, located and removed. Another very simple rule, the observance of which would in many instances have saved trouble, is never to use more than one single piece of waste or cloth for closing up an oil-hole or other opening to prevent the entrance of foreign matter. These plugs have often to be removed with a scriber point, and are sometimes pushed farther in before being finally extracted. When there are more pieces than one in a hole the one farthest from the entrance may escape detection and be left in the passage.

Another instance of the accidental presence of foreign matter in the forced-lubrication system of a high-speed engine is illustrated in Fig. 54. The pin A is bored at B and C for oil passages which meet at X. The point of the drill when drilling the hole C passes by a small amount the point of its junction with the hole B. Thus if any borings become wedged at the end of the hole C, no amount of blowing through either hole will clear them away. Should this state of things occur, these borings will almost certainly become loose when the engine has been put to work, possibly with serious results. In many instances holes which have to be drilled for the passage of oil are plugged up at one end as with the pin in Fig. 55. Cases have been known where the omission to fit such a plug has interfered with the supply of oil not only to the bearing immediately concerned, but also has dangerously lowered the oil pressure over the whole system by allowing the oil to escape through the opening. It might appear unnecessary to warn an erector not to close an oil passage by failing to cut an opening through the sheet packing used for making an oil-tight joint. Such a case occurred, however, a short time ago in a large municipal generating station. The joint in question was one between a brass elbow and the end of a crosshead pin, as shown in Fig. 56. The jointing inserted at A was blank, and thus cut off the supply of oil to the crosshead, with the net result that a new pair of brasses was required and the pin was badly cut up.

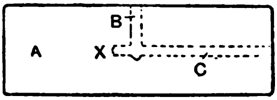

FIG. 54.

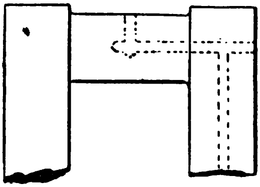

FIG. 55.

The advantage of a system of forced lubrication is that when properly fitted and installed a hot bearing is almost an impossibility, and yet small acts of carelessness or forgetfulness have caused a failure in working. It is such instances as those given above that have caused capable and ambitious engineers to be " fired," with possible ruin to their future prospects.

In fitting up a governor on a high-speed engine accurate fitting of pins in holes is not only unnecessary but inadvisable. It is an old tool-room dodge, when a plug or pin has been turned too small for a hole, to rub the surfaces of both pin and hole with a piece of oily rag. Even after the oil has been wiped off there remains a film of grease that will often transform an indifferent fit into a good one. As the governor of a high-speed engine is flooded with oil of a comparatively high viscosity, clearance for a thick oil film must be left around all pins forming joints in the mechanism. In order to make the governor respond to the slightest fluctuations in the speed of the engine it would be necessary to eliminate friction altogether, and in order to comply with the rigid specifications of electric-power station engineers as to the maximum allowable variation in speed over a range of from no-load to full load, the friction at all the governor joints must be brought down to the lowest possible limit. Thus all such joints should be free, and end-play should be allowed, to prevent collar binding. The same applies to governor rods. The greatest care should be taken that all rods point true. If the rod when fixed on its pin at, say, the bottom end does not point quite truly to its correct position with reference to the top pin, a very slight side pressure will probably bring it true. At the same time the slight side pressure required to spring the upper end of the rod into its correct position is enormously increased at the point where it is taken up by the bottom pin.

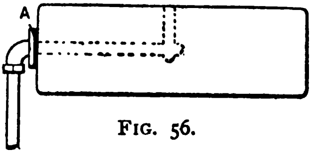

FIG. 56.

Referring to Fig. 57, which shows diagrammatically the state of things under discussion, if the length of the bottom pin is 1in. and the length of the rod between centres is 3ft., the force with which the bottom pin will be binding across corners will be 36 times that required to spring the top end into position. In the same way a very small clearance between the bottom pin and the hole in the rod will give a comparatively large movement of the top end of the rod from side to side, as indicated in Fig. 57. Even if by a very slight side pressure the top end of the rod can be coupled up, it cannot be said to point true unless the possible movement on each side of its correct position is equal. That is to say, when X = Y in Fig. 57. When rods with adjustable ends do not point quite truly they must be "thrown" in the manner described earlier in these articles in connection with main connecting rods.

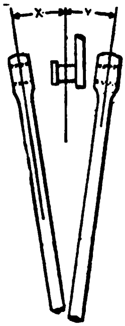

FIG. 57.

Brasses that have been soldered together for boring seldom split exactly across the centre when taken apart. For this reason one half will require to be eased at its edge before it will go on the pin. Apart from this, most adjustable brasses require to be eased on their sides, for the reasons given earlier. When a round-nosed scraper is used, a series of furrows is cut axially along the brass; and, further, these furrows cannot be commenced at the edge of the brass, nor can they be carried with uniformity to the other end of the brass. When a half-round scraper is used the results are far from perfect. In the first place, a half-round scraper is not a tool on which a great deal of pressure can easily be applied, owing to the manner in which it has to be handled. A further disadvantage lies in the fact that it is practically impossible to apply the operating force at a constant angle to the surface being scraped. Exactly the same remarks apply to the cutting angle, which cannot be maintained at a constant angle to the cylindrical bore of the brass. A very useful method of scraping out small and medium-sized brasses is indicated in Fig. 58. Referring to this figure, M is an approximately semi-cylindrical piece of wood which is placed in the brass, the latter being securely held in the vice or elsewhere. The flat scraper as shown rests with its flat side upon this wooden guide, and its cutting edge against the surface of the brass. Now, as the scraper handle is lowered, the wooden rest revolves in the brass, and as the scraper rests with its flat side upon M, the flat side always remains constant as in Fig. 59. It will be obvious to any practical engineer that a great deal of pressure can in this way be applied to the cutting edge, and long, wide uniform cuts can be taken with ease. This method of scraping out brasses was first brought to the notice of the writer by the charge-hand over the " motion " bench in a large engine works. This charge-hand had several sizes of these wood blocks made to suit the various sizes of brasses which passed through his department. The saving of time effected by this method of dealing with the job was very considerable.

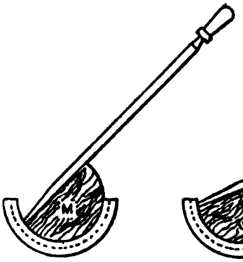

FIG. 58.

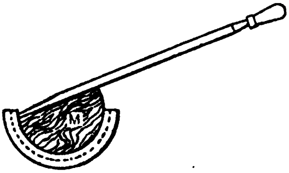

FIG. 59.

CHAPTER XVII

ERECTION OF ENGINE BEDS

THE erection of a large horizontal Corliss engine is a very different job from the erection of a modern high-speed engine upon a self-contained bedplate. In the latter case the engine can be erected upon a prepared erecting bed, as there is little below the base-line of the engine. In the case of a modern horizontal engine with the exhaust, and possibly also the steam, pipes below the engine-room floor, the bottom of the cylinders must be accessible, and consequently, owing to the various sizes of engines made by one firm, a general erecting bed is not practicable. Thus these engines are usually erected upon the erecting-shop floor, loose packings being used where required.

One of the first things that an erector should do on commencing the erection of such an engine is to study carefully the general arrangement drawing, and make sure that there will be plenty of floor space around the engine when erected. Room will be required for such operations as getting the piston rods into the cylinders, and the piston rods of large tandem engines require considerable space for handling. Before a single part of the engine is laid in place the floor space should be carefully measured up with the above point in view, so that no column, wall, or other portion of the permanent structure of the shop will come foul of the finished engine or hamper the workmen during the process of erection. With regard to the packing to be used under the engine during erection in order to gain the various heights above the floor level required, this will vary according to the weight to be carried, and also, with a view to stiffness and rigidity, will depend upon the height at which the particular portion of the engine must be carried. In the case of engines to be erected and run in this country it is more usual to fit up to the engine the receiver and such other pipes as may be deemed necessary on the job. In the case of engines made for abroad these pipes are usually coupled up to the engine in the works. In the latter case provision must be made as to available room, and also, where the receiver is below the cylinders, as to the height to which the engine is to be packed up.

Perhaps the most suitable floor for the erection of such engines is one composed of concrete with a good top skimming of granite chippings and cement. This also gives a hard wearing surface. Many floors, however, are not so well made, and some are not really suitable for carrying a heavy pressure per square foot. Thus it must always be remembered that whatever packing is used its upper bearing surface on which the engine rests is not the only consideration, but the available bearing surface between the packing and the floor must also be taken into account. A case in point was the erection of a heavy rolling-mill engine upon a new shop floor. The subsoil was loose, and not only was the concrete topping too thin, but the contractor in gauging the mixture had skimped the cement, and such as he had used was not of the best. Had the conditions been fully realized, extra large bearing surfaces on the floor under the packing would have been arranged for; but the engine was erected in the usual manner, with the result that the whole of it had to be twice re-levelled. In quite a few erecting shops the floor is laid with round sets, and this is an awkward floor on which to erect an engine. Generally baulks of timber are used as packing, and it is obvious that if the floor has been subjected to much wear and has become uneven, the timber may rest upon three points only, these points being the tops of the sets that project the highest. For the same reason this class of floor necessitates a lot of care when wedging up. A great deal of the heavy wood packing used for this purpose is not truly flat on its sides, with the natural result that it is likely to rock when placed upon the floor. In such cases, before the erector goes further the packing will have to be steadied by means of wedges, but discretion must be exercised in their use. If the wedges are driven too far under the edges of the baulk, the whole weight of the packing, and of that portion of the engine which it supports, may be taken on two or three wedges, and the bearing surface thus given may be insufficient.

The erector should bear in mind that a certain portion of the engine may be levelled up correctly, and the weight upon the packing subsequently increased by the addition of other engine parts during the later stages of erection. If the original bearing surface is not sufficient, the packing will not sustain this additional weight without undue sinking, which may throw the whole structure out of alignment. Wood wedges should have a very gradual taper, not only so as to present a large bearing area, but so as to make a more rigid and permanent job and render them less easy to displace. A very common oversight is the using of small iron wedges to raise a heavy casting off the wood packing. There is generally plenty of surface between the casting and the wedge to sustain more than the required weight, but if the wedge be a small one it will probably sink into the wood packing with any increase in weight, since the resistance of timber to compression is less than that of iron.

Another point to be considered in placing packing under an engine is that the area of each particular piece of packing under compression should be roughly proportional to the weight that will ultimately come upon it. A case in point is the packing up of a bedplate of a two-crank horizontal engine with overhung crankpin, there being only one bearing on each bed. If the area of the packing under the various portions of the bedplate is proportionate to the weight of the bed itself at various points, this proportion will no longer hold after the crankshaft is put into place. The result of dropping the crankshaft into its bearings would in this case probably cause the bedplate to sink at a point below the main bearing, since the weight upon the packing here will be greatly increased.

In considering all questions of lining-up a horizontal engine of the type under discussion the outstanding difference between this and a similar operation carried out on a modern self-contained high-speed engine must not be overlooked. It is quite true that the cast-iron bedplate of a large high-speed engine will to a certain limited extent take the form of the surface of the foundation on which it rests, but the possibilities of distortion in this direction are very small compared with that which may occur with two bedplates on separate foundations. The amount of error to be expected in levelling up the surface of a single foundation to a straightedge and level is much smaller than that which may obtain when two surfaces at some distance from one another must be made to lie in exactly the same plane.

Roughly, it may be said that the former class of engine will, as far as alignment is concerned, run as erected in the shop, whereas in the latter type of engine the reproduction of the conditions which were obtained in the shop depends upon the care and ability of the erector in charge of the job outside. Out of five engines erected in one town by two different firms during the last boom in the cotton trade, in four engines the main bearings ran hot for days after starting up, and two gave trouble for months, causing very great trouble to the engine-builders, besides injury to their good name. This points to faulty alignment in all cases, since the journal areas were ample for the purpose. It was in order to overcome this difficulty of obtaining and maintaining alignment with two independent bedplates that spherical seated bearings were introduced by one or two firms, just as spherical seated bearings for line shafting were designed with the same end in view. This design of main bearing certainly assures alignment as far as these bearings themselves are concerned, but does not of necessity prevent complications from arising in the piston line. In fact, by not necessitating the same complete rigidity of alignment, they may be the ultimate cause of hot crank and crosshead pins.

In Fig. 60 are shown diagrammatically the two bedplates of a horizontal engine, which are out of alignment to an exaggerated degree. Now, with swivel bearings—or, for the matter of that, with any bearings—the brasses could be so adjusted that the main bearings would run cool; but a different state of things would obtain where the crankpins were concerned. One of the effects would be an axial movement of the crankpin brass along the pin every stroke of the engine. For instance, during the outward stroke the big end on the bedplate B would move along the crankpin towards D, and similarly on the inward stroke the rod would slide along the pin towards C. The matter, however, does not end here. On referring to the diagram in Fig. 60 it will be seen that the angle made by the centre line of the connecting rod with the axis of the crankpin is not constant during a revolution of the engine. When the piston is at the back end of the cylinder, the angle between the centre line of the rod and the axis of the pin will be E G L; but when the piston is at the front end of the cylinder, the corresponding angle will be F H J. Now, the result of this will be that if the brass is a snug fit on the pin it will be bearing alternately upon opposite edges. There will thus be a tendency for the surface of the brass to wear into the form shown greatly exaggerated in Fig. 61. As the small end of the rod swings, in effect, from one side to the other of its central position, the curved surface of the brass will roll upon the pin.

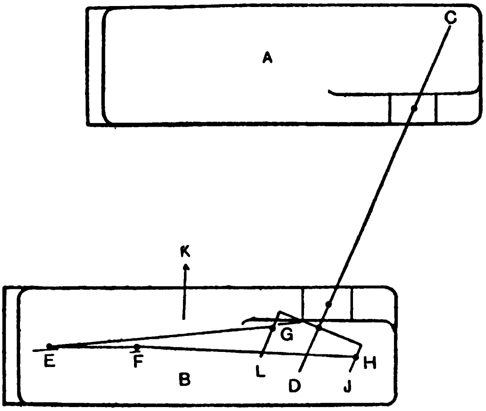

FIG. 60.

The unfortunate part of all faults in alignment which produce errors such as the above is the small portion of the brass that can be in contact with the pin at any portion of the stroke. It is bearings such as the above that are the terror of the average "engineer-in-charge." Such a bearing may have systematically run hot ever since the engine started up, and as it at last begins to knock very badly, the engineer decides to readjust and carefully scrape it up. The brass is conscientiously bedded down to the pin, and on starting up the corners of the brass will come hard on the pin, and the result will probably cause the engineer to wish that he had let it alone to pound its inefficient way throughout its life. When the crankpin brasses of an engine of the type under discussion move axially along the pin twice per revolution, it is an infallible sign that something is out of line. If the slack on each side of the crankpin brass is taken up with an audible knock, the engineer can make a shrewd guess as to where the source of future trouble may lie. It must not, however, be overlooked that a similar axial movement may be caused by the axis of the crankpin not being parallel with that of the main shaft, as explained in detail under the section dealing with high-speed engine alignment. In this case the piston line may be absolutely at right angles with the axis of the crankshaft, and no shifting of the bedplate would improve matters.

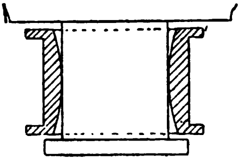

FIG. 61.

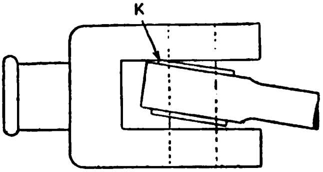

FIG. 62.

The whole extent by which surfaces in contact in various bearings are affected by errors in alignment may amount to only a thousandth or two of an inch, yet if a portion of the surface of a brass is only a couple of thousandths of an inch away from its journal, it is as useless for sharing the burden with the surface actually in contact as if it were a quarter of an inch away. It will also be noted that the error above discussed cannot be eliminated by wear of the brass, provided that the crankpin itself remains parallel. There still remains another effect produced by this error in alignment. A brief study of the diagram in Fig. 60 will show that there is a resultant side pressure on the crosshead in the direction K on the inward stroke, and a resultant pressure in the opposite direction during the outward stroke. There will also be the same rolling action on the crosshead pin as obtains on the crankpin. Now, this error actually occurred on the high-pressure side of a 2500I.H.P. engine of the four-cylinder triple type recently erected. This side of the engine always ran warm, and there was a pronounced knock as the small end moved over along the pin each revolution. A new pair of brasses was put in, and when they were being fitted it was noticed that a groove nearly an eighth of an inch deep had been hammered and worn on the side of the crosshead jaw at K in Fig. 62.

When the error is as in Fig. 60, it can be eliminated by moving the bedplate B forward towards the right; but it is, of course, possible for a similar error to occur on one side of the engine only, the other side being correctly at right angles with the shaft. In the latter case any forward or backward movement of the bedplate, as in the instance previously given, would simply throw the other side of the engine out of line, since the bedplate carries the shaft with it. It would in the latter instance be necessary to swing the bedplate which was at fault round, the pivot being the centre of its main bearing as in Fig. 63. In this figure the line A B represents the centre line of the bedplate which is correctly set, while E D shows the centre line of the bedplate which is in faulty alignment. The latter should be rotated upon D into the correct position as shown by the dotted line C D.

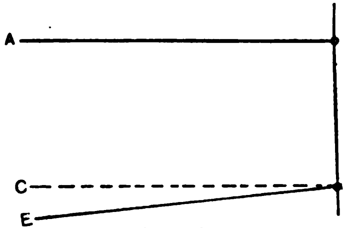

FIG. 63.

Before any movement of the bedplates is made in such cases, the alignment of both bedplates should be carefully tested so that the movement which can be most simply and easily carried out may be decided upon. The errors referred to lie in the horizontal plane, but that same state of affairs can occur in the vertical plane by one bearing being higher than the other as in Fig. 64. In this case there is no tendency such as that stated above for the connecting-rod end to slide axially along the crankpin. There is, however, a probability that the crankpin will move axially through the big end brass. This will be made clear by a consideration of Fig. 65. Taking A B as the centre line of the crankshaft, and C D as the axis of the crankpin when in its highest position, since E F will be the corresponding lowest position of the crankpin axis, the pin will have moved horizontally twice through the distance K during each complete revolution. Further, although there is no rocking movement of the brasses on the pin as in Fig. 61, it is obvious that if the bedplate be perfectly level and the crosshead pin equally so, the bore of the latter brass will be out of parallel with the bore of the big end. In the present instance the angle between them will remain constant throughout a revolution. Thus, with this error in a vertical plane, most of the harmful effects which accompany the error when occurring in the horizontal plane are absent.

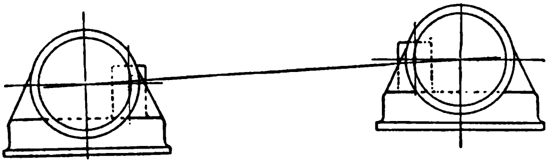

FIG. 64.

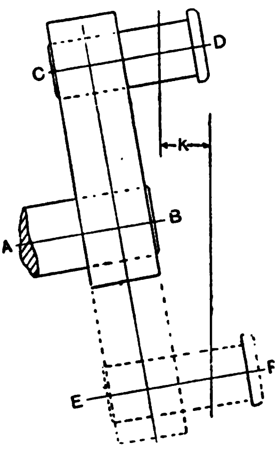

FIG. 65.

In dealing with the alignment of high-speed vertical engines the use of a vertical line was considered in some detail, but with the type of engine now under discussion the use of a horizontal line is often helpful. A taut line has a certain limited use for testing the accuracy of alignment in a horizontal plane. Where other means have not been available, such as that of setting out replace bearings for a marine-engine shaft, a horizontal line has been used with more or less success. If a line of uniform weight per unit of length and of a known modulus of elasticity be stretched between two supporting points it will always lie in a certain mathematical curve known as a catenary. Thus, under the conditions stated above, if the tension in the line is known, the amount of sag between the two supported ends can be calculated.

One difficulty lies in ascertaining the amount of tensional stress to which the line is subjected. If the line be passed over small pulleys and pulled taut by means of suspended weights, the full stress due to the weights may not come upon the line owing to the frictional resistance to any movement of the weight. A further difficulty is that of ensuring that both points of support lie in one perfectly horizontal plane. If means for ensuring this are at hand it would be reasonable to assume that by the same means intermediate points in the same plane can be found. If the two points of support are at exactly the same level, the point of maximum sag will lie midway between them; but if one point of support be higher than the other, the lowest position taken up by any portion of the wire will be nearer to, or at, the lower support. If the two points of support lie in one horizontal plane, advantage may be taken of property of a catenary curve. If a line be suspended between two points as specified, these points being A and B respectively in Fig. 66, at any two points at equal distances from A and B respectively, the amount of sag will be the same. Thus, in Fig. 66, if C be equal to D and K to L, if A and B lie in the same horizontal plane, the line O P will also be horizontal.

It is not difficult to conceive problems of alignment wherein the above facts may be of service. For such purposes it is usual to employ best piano wire, which may be pulled really taut, since its breaking stress is well over 100 tons per sq. in. This wire requires very careful handling, and should be stored upon a bobbin of fairly large diameter. Owing to its springiness it very easily becomes entangled, under which circumstances it is next to impossible to unravel it without the wire becoming kinked; and owing to the hardness of the wire it is an awkward proposition to remove a kink, as the wire will break before the kink can be pulled out. A cotton line has little to recommend it for the purpose. Owing to the shortness of the staple from which it is spun, the short fibrous ends project all round the strand, unless the whole is treated with some form of size, and it is difficult to tell what the actual diameter of the line really is. Linen is much stronger; but perhaps silk is the best of the three. As a line of this sort is liable to be accidentally broken, it is advisable so to arrange the points of support that the line may be easily replaced exactly in its correct position.

It is also often required to remove a line temporarily before its use can be finally dispensed with. If a line be fastened by means of staples driven into a wall, the best plan is to file or cut a nick in the staple in which the line can lie, and a similar device can generally be adopted wherever the end of the line is fastened. This makes the replacement of the line a short and simple operation. One of the methods used in order to get one line exactly at right angles with another consists in the application of a fairly large set square close to the point of their intersection. This is not a very satisfactory method where the length of the line is several times that of the square blade, since any error in setting the line to the square is multiplied by the number of times by which the total length of the line is divisible by the length of one side of the square. Further, it is by no means an easy operation to hold a square up against two lines without deflecting one or both of them from their true position, and, furthermore, such squares as are usually to be found in the erecting shop are notoriously inaccurate.

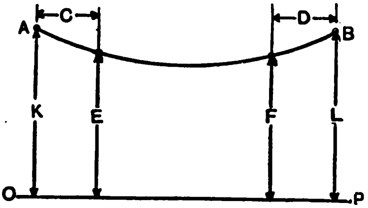

Fig. 66.

Another method is to form a quadrilateral figure by the addition of two other straight lines, each of equal length and parallel to the line opposite it. A parallelogram thus formed will have all its angles equal if the two diagonals are equal, and thus the four enclosed angles will be right angles. Now, it is not always practicable to adopt the above course on horizontal-engine work, and it is moreover a truism that the greater the number of separate measurements made, the greater will be the probable error.

Another method is based upon the fact that in a right-angled triangle the square upon the hypotenuse is equal to the sum of the squares upon the base and perpendicular respectively. It will be noticed that this method involves only three separate measurements, as against six in the method described above. Suppose that it is necessary to set out a line D F exactly at right angles to an existing line A B, cutting the latter at G as in Fig. 67. It is only necessary to fix upon some convenient point C on the existing line A B, and make C H intersect D F at a point E so chosen that $E C^2 = E D^2 + G C^2$. No abstruse calculations are required for this purpose. For instance, since $3^2 + 4^2 = 5^2$ if the lines C G, G E, and E C are in the ratio 3, 4, 5, the required conditions are fulfilled. Any multiple of the above figures will serve equally well, such as 6, 8, 10, or 12, 16, 20. A disadvantage accompanying the use of steel wire for the above purpose is that it is not easy to mark a point along its length, whereas a linen thread can easily be marked, as explained later. If a fibrous thread is used, the operation must be carried out in such a manner as to eliminate the effect of any stretch of the thread under a varying tension upon the accuracy of the measurements made. It is also obvious that the greater the length of the three sides of the triangle, the greater will be the accuracy with which the right angle is obtained. The operation is really a very simple one, and the youngest apprentice should be able to carry in his mind the figures 3, 4, 5. The line A B will have been stretched taut, and the point of intersection G of the two lines can be marked on the line A B by thrusting a fine pin through the thread. The most convenient method of procedure is now to fix to line A B at G either by placing a piece of timber beneath it and carefully driving the pin into it, or by some other suitable means. The

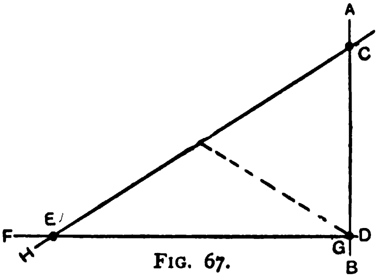

FIG. 67.

line G D can then have one end attached to the same pin, and should then be stretched taut by passing the other end of it over some fixed support, such as a trestle, and a weight be suspended from its free end. It should be so carried that it lies approximately in its correct position and can be moved sideways in either direction without varying the tension upon the line. Let it be assumed that the figures to be used are 12, 16 and 20, and that the units are to be feet. With a steel tape measure 12ft. from G on the line G A, and mark the position found by thrusting a pin through the line at C. Next bring the end of the tape to G and measure 16ft. along the line G F and mark E, the position found by means of a pin as before. Again, move the end of the tape to C and move the line F G to or from the tape as required until the point E coincides with the 20ft. mark on the tape. When this occurs, A G F is a right angle. Of course, in all such operations as the above, the lines must all lie in approximately the same plane. Referring to the triangle A C E, Fig. 68, another check upon the accuracy with which the angle A C E has been set out can be made as follows: On the line A B mark a point X 10ft. from A. X will then be exactly midway between the points E and A. Drive a nail into a trestle or piece of timber below X in such a position that when the outside edge of the metal ring at the end of the tape is held against the nail it will be exactly on X. The dimension X C will also be 10ft. if A C E is a true right angle. This follows from the well-known proposition in Euclid which proves that if a semicircle be described from a point X on a line A E, Fig. 68, any two lines drawn from A and E will at any point C on the circumference of the semicircle enclose a right angle.

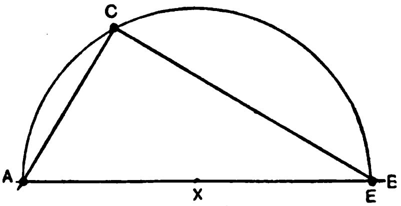

FIG. 68.

CHAPTER XVIII

THE HORIZONTAL LINE

A COMMON use to which a line is put is that of recording the relative positions of engine parts, such as those of two bedplates, in such a manner that such relative positions may be exactly reproduced when the engine is erected outside. The same method is often used in engine work other than the heavy horizontal type, the necessary lines being put upon the engine parts before erection in the works.

Imagine two separate bedplates such as those diagrammatically shown in Fig. 69, on which two lines have been scribed, each parallel with the bore of the main shaft bearings. These lines will have been marked with a carefully ground centre punch. In such cases the centre punch marks should be small and deep, and not broad and shallow, as is too frequently the case. Referring to Fig. 69, the usual method is to cut a sharp nick in the two bedplates at A and B, the two extremities of the two lines respectively. A steel wire is stretched across from A to B lying in the two nicks cut for the purpose, and a heavy weight suspended from each end of the wire. Now, if these lines are scribed across the full width of the bedplate, the length of each line A C and D B will be several times that of each main bearing, and the error involved in putting each bedplate into its required relative position will be several times

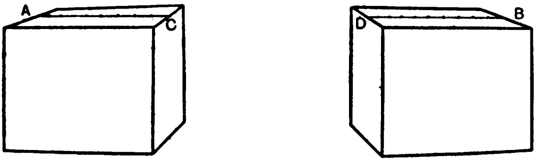

FIG. 69.

less than would be the case were the bedplates set by a line passing through the main bearings. Although the surfaces of the two bedplates may be in exactly the same plane, the wire, owing to its sag, will bear hard on the points C and D in Fig. 70, and unless provision is made for this there is a probability that the bedplates will be incorrectly set. Suppose, for example, that the bedplates are absolutely correctly set, the wire lying exactly over the lines, the surfaces of the bedplates lying in exactly the same plane. If the wire be moved horizontally towards O, Fig. 70, and then released, the weights will tend to bring the wire back over the scribed lines. It will, however, be found that the wire will not come back quite into its former position, and the same state of things will obtain if the line be moved towards P and then be released. The reason for this is, that the resultant lateral pressure due to the weights tending to pull the wire into a straight line gradually disappears as the line reaches its true position, and the very slight frictional resistance caused by the drag of the wire on the surfaces of the bedplates is sufficient to prevent it from lying evenly between its extreme points. For this reason it is always advisable to weight the wire close up to its elastic limit, and to place a little thin packing near its two ends X, Y as in Fig. 71. This packing should be of such a thickness that the wire is everywhere just clear of the surface of the bedplate. In cases where the erector who has charge of the erection of the engine in the works undertakes its re-erection outside, this means of rapidly and accurately reproducing the conditions of alignment which were obtained in the works is worth remembering.

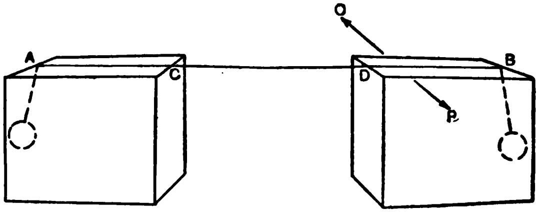

FIG. 70.

Another method for recording for reproduction engine settings is worth mentioning in passing. This method was systematized in one of the largest engineering works in the country, and is carried out by means of trammels. It is used not only to resetting in alignment of separate portions of the engine bedplate, but also to the relative positions of portions of the valve-gear and other moving parts of the engine. To apply this system to reproducing the exact relative positions of two bedplates A and B diagrammatically shown in Fig. 72, suppose that four centre pop marks are made on the bedplates at X, Y, O, P, and suppose that for convenience P X and O Y are equal. If these two dimensions are made the same outside as they were in the works, the bedplates are in the same relative positions. When the trammels are set to these points in the works, the exact distance between the trammel points is recorded upon one of the bedplates by carefully marking a position for one point of the trammel, and scribing a short arc with the other point on some convenient part of the bedplate. The lines are then permanently marked with a centre punch. Unless experience has been gained in handling trammels on accurate work, mistakes are almost certain to be made. Precautions to be used in trammel work were given in some detail in the chapter dealing chiefly with high-speed engines, and are worth careful consideration.

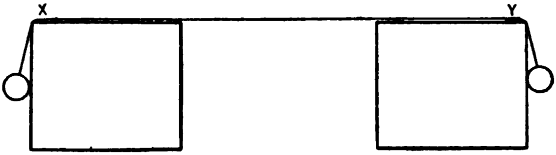

FIG. 71.

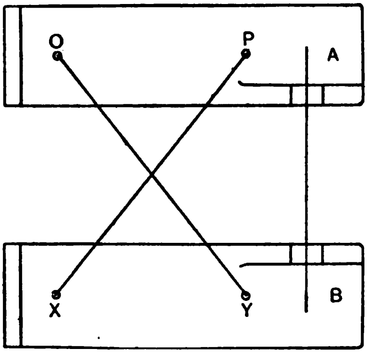

FIG. 72.

In levelling up the two bedplates the initial method of procedure depends somewhat upon the conditions at the time. If the bedplates are already placed approximately in position upon baulks of timber, the higher of the two should be levelled up accurately before the other is touched. Should the lower of the two be tackled first, it might be found necessary, in order to drop the second bedplate to the same level to remove an 18in. baulk of timber, and substitute a baulk slightly less in depth; whereas, by starting as recommended above, the second bedplate can in its turn be easily brought up to the level of the first one by the addition of a little packing. Should, however, the bedplates be in the process of erection outside, and, as is usual in such cases, be required to be bedded down on a stone foundation, it is obvious that the lower of the two should be levelled up first, since neither can be packed up off the stone. Should it be attempted simultaneously to bring the surface of each bedplate level in itself, and also to bring the surface of both bedplates into the same plane, a waste of time will almost certainly result.

What is considered by the writer to be the best and quickest method of levelling up a single bedplate has already been exhaustively described. Probably the best way of raising the second bedplate to the level of the first is by use of a long straightedge in conjunction with a really good spirit level. The straightedge will be laid across the two bedplates, and the spirit level placed upon the former. The first object should be to get one particular portion of the second bedplate to the same height as the first, and not to raise the former to the correct height and to level it up simultaneously. Let the bedplate that has already been levelled up be A, and the bedplate that has still to be raised to the correct height, and also to be made level in itself, be B in Fig. 73. Suppose in the first instance that the straightedge rests upon the bedplate B over a point O, and wedge packings R and P are driven in until the point O is at the correct height. Now, the spirit level is transferred from the straightedge to the bedplate B, and let it be supposed to have its side Y lower than the side X. If the wedge R be then driven further in to improve the level of B regarded by itself, it will be observed that each time B is raised at Y the point O will also be raised by a less amount. This will, of course, again alter the relative heights of the two bedplates, and the spirit level will again have to be placed upon the straightedge, and O lowered by knocking further out the wedge P. On the other hand, suppose that the point O whereon the straightedge rests is directly over a packing P, and the other two packings R, R are disposed approximately as in the plan view in Fig. 74; no adjustment of the packings R, R will alter the height of the bedplate at O after the latter has once been set. The work of levelling the second bedplate B can then be proceeded with, and as it rests upon three packing wedges, and only two of these require to be adjusted, the job is a very simple and straightforward one. Before leaving this portion of the subject it may be as well to revert to the possibility of the use of a taut line in place of a straightedge, and it is quite conceivable that a long straightedge might, under certain circumstances, not be obtainable.

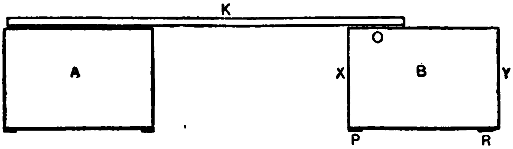

FIG. 73.

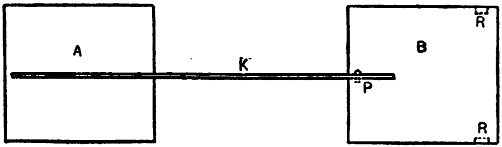

FIG. 74.

One of the properties of the catenary curve has been previously pointed out and illustrated in Fig. 66. Its practical application will now be considered in the present case. Suppose that the bedplate A has been carefully levelled in every direction, and a steel wire is stretched across both bedplates as in Fig. 75. If the dimensions X and Y are equal, and L and K are equal, it does not necessarily follow that the upper surfaces of both bedplates are in the same plane. This is shown in Fig. 76, where the bedplate B is very much out of level, but L is made equal to K by raising B bodily. However, this inaccuracy would be shown by a spirit level resting upon the upper surface of B. Thus, since A has been already levelled up, as long as B, regarded by itself, is kept horizontal

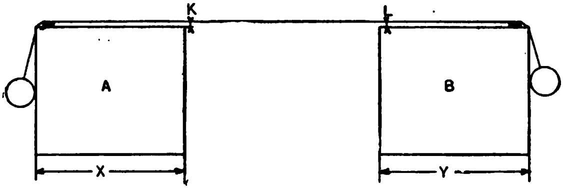

FIG. 75.

by use of the spirit level, it can be raised or lowered bodily as required until L is equal to K. Both bedplates will then be at the same height.

An error that is not to be met with very frequently in serious proportions is lack of alignment between the bore of the cylinder and the crosshead guides. This form of error is by no

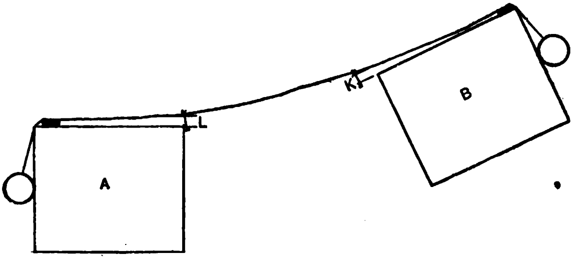

FIG. 76.

means unknown, and the possibility of its occurrence to a harmful degree depends to a great measure upon the method used for attaching the cylinder to the bedplate. In some designs correct alignment, or otherwise, depends mainly upon the care and skill of the erector; in others it is chiefly decided by the degree of accuracy in the machine-tool work.

The chief disadvantage of the horizontal engine lies in the wear of the bottoms of the cylinders due to the weight of the pistons and rods. In some cases tail-rods and guides are fitted to take the above weights, and one firm has arranged in its standard designs for a white-metal slipper at the bottom of the piston, which forms part of the piston itself. This block is made adjustable for wear, and as the white metal wears before the cast iron of the cylinder, this defect in horizontal engines is thereby largely nullified. In cases where the piston rod is supported by slippers at both ends it is obvious that there will be a considerable deflection of the rod if the weight of the piston is to be taken on the guides, and in order that the piston may float in the cylinder it would be necessary to place the latter lower than true alignment would demand. One well-known firm gives all its rods so arranged a certain amount of camber on the upper side, so that when the weight of the piston comes upon them they will be straight and linable. The amount of sag of the rod with a known weight of piston is a matter for simple calculation, but it is not so easy to bend the rod to such a curve that the weight of the piston will bring it into a dead straight line. With the old type of piston-rod stuffing-box, heating of the rod was a common occurrence; but with modern metallic floating packing the trouble has been practically eliminated. Most of the metallic packings now on the market allow for considerable errors in alignment, and for the dropping of the rod due to wear of the bottom of the cylinder.

In Fig. 77 the crosshead guides are shown out of line in a vertical plane with the bore of the cylinder, to a greatly exaggerated degree for the sake of clearness. It will be seen that as the piston moves from one end of its stroke to the other, the rod moves vertically in the stuffing-box by an amount approximately equal to K in the diagram. It will also be noticed that when the piston is at the extreme outward end of its path—that is, at the end of the cylinder marked A—there is a tendency for the crosshead slipper to rest only upon its tip P, and that in order to allow the whole bottom surface of the slipper to rest upon the slide it would be necessary for the piston rod to have a downward curvature.

Turning now to the piston, it is evident that when it is in its extreme inward position—that is, at the end of the cylinder marked B—it rests only upon its outside edge X. During the outward stroke this edge will scrape along the bottom of the cylinder. A case in point is that of a horizontal engine manufactured by one of the best-known American firms, which was put down in a London power station. From the very start this engine gave trouble in the lubrication of the cylinder, and with varying groans was constantly " asking for oil." The lubricators were overhauled, the feed increased, and a heavier lubricant used in the cylinder with little improvement in the running. At the first opportunity the cylinder cover was removed, and a quantity of cast iron which had been scraped out of the bottom of the cylinder was swept out. The cylinder was grossly out of line with the crosshead guides, and the state of affairs referred to above obtained in this instance. An examination of the piston showed that it had worn round at the bottom, and that at no position of the stroke had it enjoyed a decent bearing surface on the bottom of the cylinder. Within five weeks after starting up the makers' representatives decided to fix a complete new cylinder, so great had been the wear. American cast iron is notoriously soft, and this cylinder was specially so. In fact, the cast iron composing it had a strong family resemblance to graphite. It was, however, fully admitted that the lack of alignment which obtained was a strongly predisposing cause of the trouble.

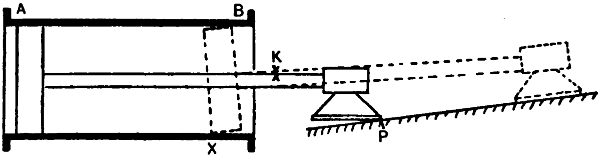

FIG. 77.

Engineers of fairly wide experience will probably have come across cases of two engines side by side, by the same makers, and under identical conditions of steam pressure and temperature, where one has required perhaps double the quantity of cylinder lubrication required by the other. In such cases it may be worth while examining the alignment of the cylinder and the bearing surface of the piston along its bottom.

CHAPTER XIX

HORIZONTAL ENGINE BEARINGS

IN a tandem horizontal engine, if the two cylinders are on the same crank and one straight line will pass through the axes of the two cylinders, each cylinder will bear the weight of its own piston and the due proportion of the weight of the piston rod. Where there is a common bedplate carrying the two cylinders, there should be little trouble in obtaining true alignment, but in many engines the only rigid connection between the two tandem cylinders consists of one or more distance-pieces. Thus the accuracy of alignment obtained depends upon the care with which the surface of the masonry bedplate is dressed up. If the axes of the two cylinders are parallel, and yet one is higher than the other, the higher cylinder will relieve the other one of a portion of its load, since the piston rod will sag. The worst state of affairs would occur should the large cylinder be seriously lower than the small one, since the tendency would be to transfer a portion of the weight of the larger piston to the comparatively small supporting area under the smaller piston. It should be noted, however, that owing to the lack of stiffness of the rods in a vertical plane, the cylinders must be very seriously out of line in the manner referred to, before any serious transference of the weights of the various portions of the piston line can take place. However, with the old-fashioned tuffing-boxes and soft packing, such lack of alignment would probably lead to trouble with the rods, whereas floating packing eliminates such trouble, unless the cross movement of the rod in the stuffing-box exceeds the amount of play provided for. Another case is that in which the axes of two tandem cylinders are not parallel, and the writer has come across some bad examples, the worst cases of which, however, have been due to the sinking of a portion of the engine foundation after erection. As, however, the piston rod is almost invariably turned down to a smaller diameter where it passes between the two pistons, the flexibility of the rod will generally allow the piston to follow the bore of both cylinders without giving rise to any serious stresses.

The bedplates being lined up and correctly set, the crankshaft may be dropped into its bearings. The conditions under which the main shaft bearings of a horizontal engine work differ from those obtaining in a vertical engine, and this has led to the design of bearings with wedge adjustment for the former type. As no erector can intelligently bed in a shaft without fully grasping its working conditions, the point is worthy of notice. The simplest form of adjustable bearing is that illustrated in Fig. 78, in which the external stresses on the shaft are purely torsional, and the wear of the bearing is that due only to the weight of the rotating shaft and any revolving parts carried by it. It is thus obvious that any wear on the bearing can be taken up by removing the requisite amount of stock from the edges of the bottom brass at D, D. A similar method would apply were the stresses upon the shaft alternatively upward and downward, although in this case the wear would take place upon the top brass as well as upon the bottom one—that is, supposing that the upward forces were sufficiently great to overcome the weight of the masses lying about the shaft. In order to take up the wear in this case accurately it would be necessary to remove stock from the edges of the top brass, as well as from the edges of the bottom brass, if the original neat fit of the brasses round the shaft is to be maintained.

In a vertical double-acting engine there are certain horizontal resultants about the shaft, but the chief forces are in a vertical plane as above. It is also noteworthy that as the brass wears, due to vertical stresses, there is a tendency to take up a little horizontal wear due to the shaft wearing deeper into the two halves of the brass. In a horizontal engine a great proportion of the forces acting upon the main bearings are in a horizontal plane. In large horizontal engines used for rope driving, the weight of the large rope wheel brings a considerable downward pressure upon the bottom brasses, and a compromise is sometimes effected by making the brasses as in Fig. 79, the direction of the line A B being supposed to represent that of the mean resultant during one complete revolution of the engine. This disadvantage of the ordinary split bearing is that, unless the shape of the bearing surface is altered, adjustment for wear can be made in one direction only. For instance, in a horizontal engine the bearings tend to wear as in Fig. 80, and if the brasses are split horizontally, merely letting them together only leaves a fraction of the original bearing surface taking the horizontal stresses. Many large main bearings for horizontal engines are for this reason fitted with horizontal wedge adjustment as diagrammatically shown in Fig. 81, the bottom brass C being fitted into the bedplate in the ordinary way, while the brass blocks A and B are made to slide horizontally, and are adjusted by the vertical movement of the mild-steel wedges D and E.

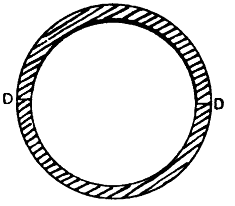

FIG. 78.

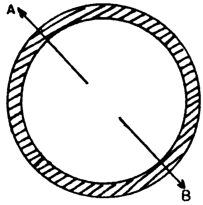

FIG. 79.

It will be noted that there are three sides to be fitted in these side brasses—namely, the curved portion A, the bottom B, and the back C, which beds against the side of the mild-steel wedge. The reference is to Fig. 82. The proper fitting of these surfaces is most important. Suppose that when the surface A is in contact with the shaft, the surface C does not bed fully up against the wedge at W, there is a tendency for the shaft to come hard on the side brass at X. Further, A and C must bed up against the shaft and wedge respectively for the full length of the brass.

Fig. 83 is a sectional plan of the side brass, and it is evident that if there is an opening between the brass and wedge E at one end Z, the greater part of the working pressure will be taken upon the side brass at K. The probable result of this will be a hot bearing. In fact, this type of bearing demands the full skill of the erector in fitting it up. Fortunately, if the bearing, though faulty in the above respect, will run cool at all, every revolution of the engine improves the bed, the error tending to correct itself as the bearing wears. One of the weak points of this bearing is that only a portion of the brass can be adjusted horizontally, and, as will be shown later, the brass is a difficult one to adjust.

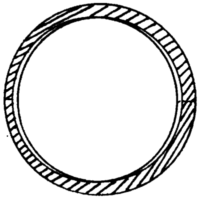

FIG. 80.

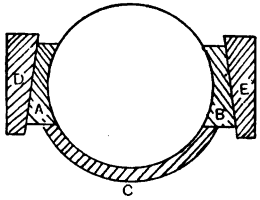

FIG. 81.

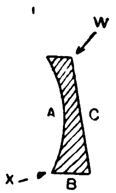

FIG. 82.

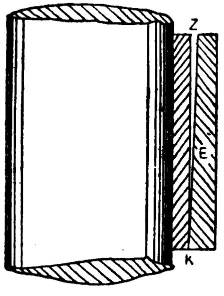

FIG. 83.

Fig. 84 shows diagrammatically the state of affairs when the bearing has worn. There is then a flat surface under the shaft at the bottom of the brass at A, and during one complete revolution of the engine the shaft rolls alternatively towards B and C, in both cases bedding fully upon the sides of the bottom brass, and upon the side brass. Now, if the wedges are so adjusted as to bring the side brasses up to the shaft when the latter is in its central position as in Fig. 85, it will be seen that the weight of the shaft is supported in the brass at the point A only. In the case of large engines, where the weight of the fly-wheel runs into many tons, such a bearing surface may be totally inadequate, and cutting and heating of the brass result. Similarly, heating will probably arise should the side brass R in Fig. 86 not bear hard up against the shaft when the latter is in contact with the bearing surface T S of the bottom brass, since the shaft will then tend at a certain portion of the stroke to roll upwards against the corners of the bottom brass. To put this aspect of the matter into a few words, and referring to the same figure, the bearing surface taking the horizontal stress is divided into two portions, T S and R, both of which are essential. One is adjustable and the other is not, and the only way of keeping this class of bearing in proper condition is to have the side brasses adjusted neat up to the shaft, so as to take the greater portion of the horizontal stresses from the bottom brass. There is a further point about these bearings that is worth attention. The wedges referred to are usually held and adjusted by two screws A and B, Fig. 87. A little consideration will show that if the set-screw A is screwed farther in than the set-screw B, so as to raise one end of the wedge higher than the other, the result will be that the side brass is bearing upon the shaft at one end only. This is made clear in Fig. 88, which illustrates the conditions described, the point F alone taking the thrust of the engine. As these bearings are usually designed, when the cap is in place the position of the wedge cannot easily be seen, and the whole

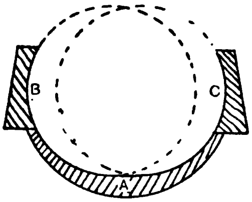

FIG. 84.

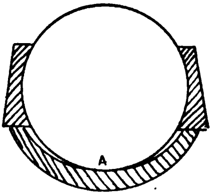

FIG. 85.

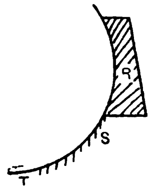

FIG. 86.

adjustment has to be made "by feel." In order to avoid heating troubles, a common practice is to close the brasses a little at a time, and so extend the process over a considerable period. This method is really based upon bad reasoning, since, however slowly the danger zone be approached, there may come a time when the final turn to the adjusting screw will produce a hot bearing. Perhaps the better way is to get the side brasses snug up against the shaft, and then ease them back by a definite amount. If a note is taken of the amount of this, and of any future forward adjustment of the side brass, the erector will always know what amount of play there is in the bearing. Suppose that the bearing has worn slack and requires adjustment, it is evident that the shaft will move about in the bearing, and the position of the former will depend upon the position of the crank when the engine comes to rest after the steam has been shut off. If, after stopping, the engine is turned into a more suitable position for working at the bearing, the thrust from the teeth of the pinion of the barring engine will probably again alter the position of the shaft in the bearings. It is also possible that all the adjustment may be made on one side of the shaft, and if the engine is allowed to come to rest naturally, it will probably result from the position taken up by the crankshaft that the chief adjustment made with the side brasses of the two bearings will be made upon opposite sides of the crankshaft, and this may cause trouble. In bearings of this type intelligent fitting and adjustment are necessary, which presupposes a thorough understanding of the functions of the various parts and surfaces.

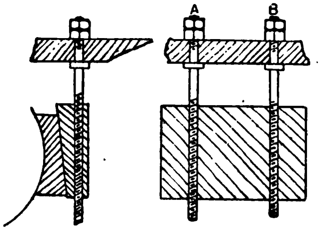

FIG. 87.

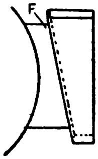

FIG. 88.

CHAPTER XX

FITTING OF KEYS

A REALLY good job should always be made of the keying on of engine fly-wheels. The stresses which are likely to come upon the fly-wheel keys of an engine depend upon the nature of the work which it is set to do. In rolling mill engines and those used for electric traction the stresses are often severe. It is difficult to calculate what will be the stress per unit area on keys, since the amount of the surface supporting the working stresses depends so largely upon the class of the workmanship put into the job. Thus for these keys a bed approaching perfection should be aimed at, whereas an inspection of the average key fitted in an engine will show that not more than one-third of the calculated area is available to meet the stresses to be encountered. In bedding in most working surfaces that are in motion relative to one another, reliance is placed upon the fact that the bed is improved with every revolution of the engine, but in the case of a key, any improvement in its bed can only take place by the key becoming slack. Further, as soon as the slightest slackness occurs, hammering takes place, and both the key and the keyway very rapidly deteriorate, and the final result may be a breakdown or a cracked boss. Perhaps the most severe service imposed upon fly-wheel keys is met with in gas engines. Here cracked fly-wheel bosses are a not infrequent occurrence, and with some gas-engine starters the shock on the fly-wheel keys is enormous. Although the keys in steam-engine fly-wheels are not usually exposed to such sudden shocks as are met with in gas engines, they often have to stand shocks the severity of which is not always realized. If the varying pressure on the piston, as shown by the indicator diagram, be corrected so as to allow for the inertia of the moving parts, very sudden rises of pressure on the crankpin will often be found to exist. Except in " staked " fly-wheels, the general practice is to cut a keyway both in the shaft and in the boss of the fly-wheel. Referring to taper keys, it is quite a common thing to hear a workman discuss whether a key should bind on the sides or not, and it may often be heard as an excuse that the workman was not aware that the key should bind on the sides when he is being reprimanded for leaving an imperfectly-fitting key. It may be definitely stated that for keys for this class of work, side fitting is of at least of equal importance to top and bottom fitting. It is certainly more difficult to get a proper bed on the sides of a taper key than on the top and bottom, since in the latter case the bed may always be improved by letting the key a little farther in. On the other hand, should the key be inadvertently reduced below size, measured across the sides, the only real remedy is to fit another key. Of course the fitting of a good key presupposes a good keyway both in the shaft and in the wheel. It is also necessary that both keyways exactly coincide. As a matter of fact, they always require a little dressing up with this point in view. Sometimes the inaccuracy is due to the shaft not being set with perfect exactness on the machine when the keyway was cut, or to the inaccuracy of the machine tool. It may also arise in the keyway in the wheel boss due to the same causes, or to the side-spring, or the side-play of the tool in the slotting machine.

In this class of work not fewer than two keyways are employed, and where there are two keyways only, they are put in at right angles to one another. In this case, perhaps the best way to get perfect coincidence of the keyway in the wheel, and that in the shaft, is as follows: First of all, the wheel is carefully set in such a position on the shaft that the keyways coincide as nearly as possible. Then a temporary key is driven in one of the keyways to hold the wheel as set. A drift or broach of the same finished width and depth as the small end of the keyway is then driven through the other keyway. This drift should not be less in length than the length of the keyway in the wheel. It must be admitted that with many firms the keyways are simply filed out to make them linable, but the method of using a drift is both more accurate and far more economical, and has been used on gun machinery and mountings for many years. The firms who use these drifts have, of course, standardized their keyways. One style of drift is shown in Fig. 89, but a form that has been found to give good results consists simply of a length of hardened and ground tool steel of the desired section, and being ground on the cutting end on the periphery of an emery wheel of small diameter, gives an angle of a little less than 90° on the cutting edge as in Fig. 90. The use of this tool will meet every requirement where the top and bottom of the keyway are parallel with one another, but when the keyway is tapered it would finish it correctly at the small end only, the large end of the keyway being left as shown, greatly exaggerated, in Fig. 91, K being the amount of the taper in the length of the keyway in the wheel. In order to finish correctly to size all over the keyway, a drift consisting of two parts is now used, the lower half giving the correct taper and the upper half being driven through the keyway after being well oiled on its lower surface, as shown in Fig. 92.

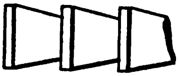

FIG. 89

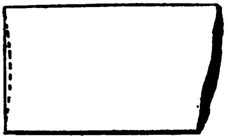

FIG. 90.

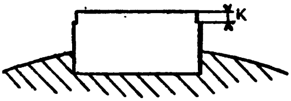

FIG. 91.

The old millwright's method of fitting a key was first of all to make a wooden pattern of it, planing down a piece of soft wood and bedding it carefully into the keyway. The millwright then took the wooden key to the blacksmith's fire and forged a wrought-iron key, using the wood one as a templet, leaving just sufficient allowance for grinding off the scale on a wet stone, and fitting. This method of using a wood model for large keys is found in many shops to-day. In more modern establishments keys are generally ordered from an outside firm specializing in the manufacture of such goods, and are made within narrow limits of accuracy.

It is surprising that the scraper is not more generally used in fitting in large keys. In shops in the North of England where heavy millwrighting is a speciality, the use of a flat scraper for this purpose has been found to be essential for getting through the work. On the other hand, there are many large works where the sole use of the file for letting in keys is the general practice. A fitter trained in the use of a scraper will run right away from the man who pins his faith to the file. It is not here suggested that the use of the file should be entirely excluded from this class of work, but, certainly, all the heavier work should be done with a key scraper. There seems to be an idea in some quarters that a scraper should only be used for finishing work. When the late Sir Joseph Whitworth first introduced the scraper into his works he had the greatest difficulty in persuading his men to use this tool, and the prejudice does not appear to have entirely died away.

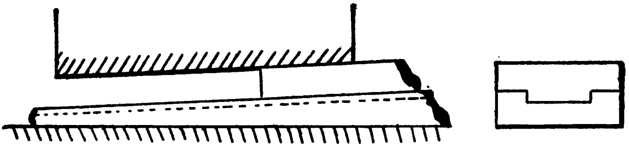

FIG. 92.

If a scraper, as ground for finishing work, is used in key bedding, the result will be disappointing. The cutting edge should be ground to a much more acute angle, and this presupposes good quality steel if the edge is to stand for any length of time. Many hundreds of such scrapers have been made by simply grinding the end of a half-round file, and have given excellent service. When files are subjected to this test it will quickly be found that they vary very much in quality. To obtain the best results the scraper should be made of good quality of tungsten steel. It is a really surprising thing, when the enormous advantages of high-speed steels for cutting in machine tools have been universally recognized, that its use should not have been extended more largely to other tools. High-speed steel has already been found essential for pneumatic chippers, caulkers and riveters. The present state of affairs enables a fitter who can get hold of a few hand tools of various descriptions made of high-speed steel easily to outdistance his fellow workmen who are not similarly equipped. Returning to the key scraper, it is evident that the much more acute angle of the cutting edge will enable the workman to hold the handle of the scraper much nearer to the work, as in Fig. 93. Thus the resultant forward pressure is much greater, and a comparatively small pressure is required to make the cut. With this scraper the metal is removed in long thick shavings. Another point to be noted in grinding this scraper is that a greater curvature may be used on the cutting edge. It is obvious that with a given curvature of the cutting edge the less the inclination of the scraper to the work, the greater will be the width of the cut, and as in the type of scraper under discussion the angle of inclination is smaller than with other types, a greater curvature of the cutting edge is desirable.

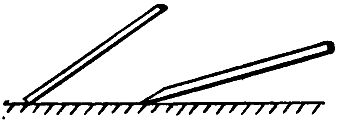

FIG. 93.

When plain keys, as distinct from gib-headed keys, are used, the only way of getting a key out that has been tapped in for bedding, is to drive it out from the other side, and to prevent it from becoming burred up at the end during the process, and thus giving it a false reading, it is advisable, before commencing to fit the key, to chamfer the edges well at both ends as in Fig. 94, although this operation is generally left until the job is finished.

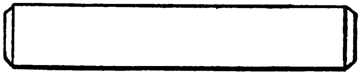

FIG. 94.

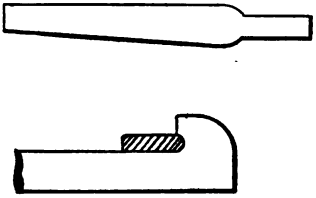

FIG. 95.

Various methods are used for drawing a gib-headed key while fitting, and most of them deform the key head. Possibly the best method, and one that is adopted as a standard in many works, is the use of a taper drift as shown in Fig. 95. The pressure is then applied in the proper place—that is, at the root of the head. To enable this tool to be used a small groove is cut in the key head as shown.

CHAPTER XXI

GENERAL

THE operation of " staking-on " a fly-wheel is one that requires not only judgment and care, but, if the job is to be carried out with efficiency and dispatch, some experience is also necessary. For this purpose the wheel is bored out larger in the boss than the diameter of the shaft in the position where the fly-wheel is to be keyed. The large fly-wheels used for rope driving in the Lancashire cotton mills are usually cast in segments which are machined and bolted together. A flat is cut along the shaft on not fewer than four sides, and corresponding keyways are cut in the boss of the wheel. The method of truing up the wheel on the shaft is similar in principle to that adopted in truing up a bicycle wheel. Temporary keys with rounded backs are driven in between the shaft and the wheel in the spaces between the keyways, and these keys are so adjusted that the centre of the fly-wheel coincides with the centre of the shaft, and the axis of the fly-wheel is parallel with that of the shaft. With a bicycle wheel this result is arrived at by holding a piece of chalk alternatively against the side of the rim and against its periphery as the wheel is spun round. In the case of the fly-wheel more accurate means are adopted in the shape of a stationary fixture rigged up against the rim of the wheel. As the method is more or less one of trial and error, speed and accuracy in getting through the job can be obtained only by practical experience. Whilst the wheel is held by the temporary keys, the permanent keys are fitted in the usual way.

There was a certain saving of expense in the days of cast gears by using staked wheels, as there was no necessity in this case for the wheel to go into the lathe at all. At the present time the advantage of the staked wheel is not very obvious, and it certainly does not make such a good job as is obtained by boring out the wheel to fit the shaft and using sunk keys. With the former method it is a common thing, when going round the keys with a hammer after a trial run on the engine, to find that they have become a little slack and can be driven farther in. In putting a fly-wheel made up of two or more parts round its shaft, careful slinging is required, and several serious accidents have happened during this operation. In one case an oversight in providing insufficiently rigid packing allowed the engine shaft to turn round through part of a revolution owing to the unbalanced state of the fly-wheel, which was only partially fitted together on the shaft. This oversight put two men in hospital. In re-erecting a staked fly-wheel it is evident that if one key be driven farther in than was previously the case, the key opposite cannot be driven in as far as originally, and the wheel will then be partly eccentric. Thus, before stripping, the keys should be marked with this point in view.

One of the first jobs about the erection of a Corliss valve gear is the chipping up of the ports in the cylinder. It is of importance that the operating edges of the port and valve be true and linable. It is also desirable that the valve admits the steam instantly along its full working length. The common practice is to leave on the edges of the ports in the cylinder a certain amount of metal both for finishing and to allow for any slight shifting of the core in the sand. As it is impracticable to machine these edges, they are trimmed up by hand. In order to get a line to chip to, a straightedge of at least as great a length as the port is laid in the latter after the machined surface of the port has been chalked, and a line is drawn along the edge of the straightedge with a scriber. It may here be remarked that the majority of scribers to be found in an erecting shop are more like centre-punches than scribers. To get anything like accurate results a scriber should be ground with a long fine point. In order to get the line referred to parallel with the bore, the straightedge must be sufficiently rigid not to sag, and when this requisite has been fulfilled, the straightedge will be parallel with the bore of the port when it rests equally upon both its edges—that is, assuming that its edges are of equal thickness and parallel, and are also free from "wind." To ensure that the straightedge rests as described it is advisable to place two small pieces of paper under the edges of the straightedge at each end, and then by just gently pulling at each piece of paper in turn it can be ascertained whether each piece of paper is taking its due proportion of the weight of the straightedge.

Having scribed the lines to which the edges of the port must be cut, the next thing is to obtain a suitable chisel. Owing to the length and comparative smallness in diameter of the port, it is obvious that the angle of inclination of the chisel to the line of cut must be small, and thus a chisel as ordinarily ground cannot be used. Further, a chisel of much greater length than ordinary will be required, which means that its point will be less readily under the control of the fitter. The chisel must therefore be unequally ground at each side of its cutting edge as in Fig. 96, in which the chisel as ordinarily ground is shown, and also a chisel ground for present use. It should be noted that a chisel should always be so ground and held when cutting along a flat surface that the flat side of the chisel rests squarely upon the finished surface. The vertical resultant of the force of the blow struck upon the end of the chisel flattens out and smooths the finished surface of the metal after the cutting edge has passed over it. In the case of the second chisel the smaller angle of inclination of the chisel to its work causes a smaller vertical resultant, and the "fullering" action is thus less. Therefore, in order to get the best finish upon the job, the angle of inclination referred to should not be any less than is actually necessary, and the chisel point should be carefully ground accordingly. The edges of the valve have also to be trimmed up, and it may be well to mention a point that is often overlooked.

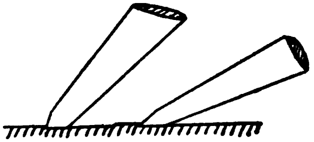

FIG. 96.

Corliss steam valves should be put in the lathe in such a manner that the cutting edge of the tool meets the steam edge of the valve. Should the reverse be the case, the edges of the valve are often broken away as the tool leaves the metal, and if there is not much stock left for clearing up after turning, a good steam edge often cannot be obtained. On the other edges of the valve, which perform no function, a clean edge is not important. Lines representing the edges of the ports should always be produced on the back of the cylinder port, and the same remark applies to the corresponding end of the valve. It is then possible, after simply removing the end cover, to see at a glance the exact relative positions of the working edges of both valve and port for any angular position of the former. This greatly assists the setting of the valves.

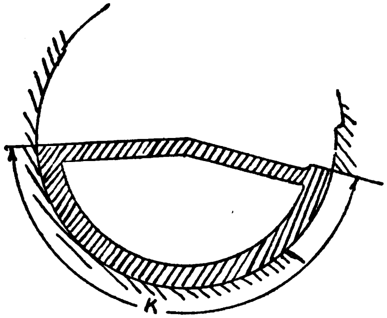

FIG. 97.

In valves of any size one or more ribs are arranged in the shape of discs as shown in the transverse section of the valve at A B in Fig. 99, and opposite their working positions corresponding ribs are cast in the ports. The idea is to prevent the edges of the valve from being forced in the port owing to the deflection of the valve due to the pressure of the steam or to its distortion due to high temperature. Should this occur, the edge of the valve would foul that of the port. These projections, as well as those at the end of the valve, also serve the useful purpose of providing the turner with a means for calipering the diameter of the valve.

There are other two points to be noted. One of these is that the angle K in Fig. 97 must be less than 180°, otherwise the valve will not remain tight should wear take place. This is clearly shown in Fig. 98, in which the angle enclosing the working edges of the valve is greater than 180°. As the valve wears down at N, a space is left at each side of the valve at M M. The second point for the fitter to note is that in steam valves the projection A B, Fig. 99, must be chipped away at the upper half of its circumference. The object is to give the valve a certain amount of freedom to lift off its seat in the case of emergency, and so act as a relief valve to the cylinder. Should circumstances arise to give an early compression in the cylinder, a serious rise in pressure at the end of the stroke would thus be prevented, the valve being simply lifted from its seat, the steam in the cylinder being forced back into the valve-chest. It would also act as an emergency outlet for water should a sudden rush of condensed steam into the cylinder take place. Valve spindles are often made with a palm forged at one end, and this palm fits into a slot in one end of the valve. In the same way clearance must be left top and bottom both to allow the valve to follow up the inevitable wear, and to allow the valve to lift off its seat as described already. The palm should, however, be a nice sliding fit in the slot at the end of the valve. Should any slackness be allowed here the palm will be doing its work at its opposite corners as in

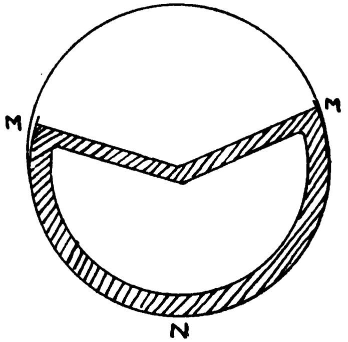

FIG. 98.

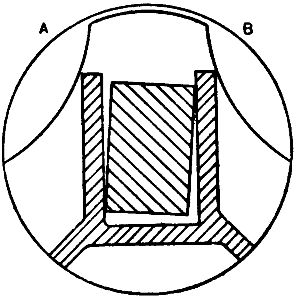

FIG. 99.

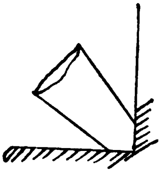

FIG. 100.

Fig. 99, and these will soon be hammered away, and a good deal of backlash result. The valve spindle levers are keyed on to the spindles in a certain angular position relative to that of the operating edges of the valve. When the position has been obtained it should be recorded by a very fine chisel cut both on the lever and on the spindle. A special chisel is required for the purpose as in Fig. 100. It is ground to two fine edges at right angles to one another, which meet at the point. When using this chisel the mark is cut simultaneously on spindle and lever. When afterwards setting the lever on the spindle to these marks, the best method of checking the accuracy of the setting is to take a scriber which has been ground to an exceedingly fine point, and, placing this point in the chisel cut on, say, the lever, it should glide smoothly into the chisel cut on the spindle. This is really a more accurate method than that of working to sight. An error in the angular position of the lever as measured on the circumference of the spindle is multiplied several times when measured at the end of the lever.

CHAPTER XXII

CORLISS VALVE GEAR

THE position of the keyway in the valve spindle is carefully marked off from that in the lever, with the latter in such an angular position that the marks before referred to coincide. After the keyway in the valve spindle has been cut it is quite possible that one or both sides of the keyways may require to be drawn a little in order to bring the datum lines exactly fair with one another. It should be made certain that the desired accuracy has been obtained before any attempt is made to fit the key in place. The stresses on the valve spindle keys of a Corliss trip gear are severe owing to the plucking action of the dashpot and catches, and it is essential to provide plenty of surface to take these stresses by having large keys. The key should also be made wide in proportion to its depth, the old-fashioned square key not being suitable for this purpose. In a key that is narrow in proportion to its depth there appears to be a tendency to turn over as shown in Fig. 101, and it will be obvious that the wider the key in proportion to its depth, the less will be the tendency referred to. Exceptional care should be taken in fitting these keys. The valve spindle should, of course, be left sufficiently long to allow the head of the key to rest in the extended keyway with a view both to facilitating the fitting and subsequent withdrawal of the key, and to obviating the danger of the head of the key catching the engineer's clothes when the engine is at work.

One or two firms who build large Corliss engines secure the valve levers to the spindles by means of set-screws. In such cases a fine-pitched thread is used in order to lessen the danger of their slackening back. They are, of course, fitted with lock-nuts. This is not a very desirable method, and is one that calls for exceptionally good workmanship. In the first place the thread portion of the set-screw must be a neat fit in the tapped hole in the lever, as also should be the check-nut on the set-screw. The check-nut must also bed all round its face upon the facing provided upon the lever. If it is bearing upon only one side, as in Fig. 102, it will assuredly become slack sooner or later. When such a check-nut beds fairly, the stress is taken upon the whole area of the thread as in Fig. 103; but when the nut is as in Fig. 102, the stress will be taken solely on the tip of the thread at one point only as at A in Fig. 104. If the set-screw is a trifle easy in the hole the check-nut may be made to bed all round its face by straining the set-screw over as shown. This would not improve the condition of affairs as illustrated in Fig. 104. The proper way to ensure a proper job being made is to rub a little marking on the under side of the nut and to screw it gently down with the fingers or with a spanner until it just touches the face on the valve lever. If the nut beds only at one point, this will be clearly shown by the marking on the lever. Any high place on the lever should then be filed down until a satisfactory bed is obtained. Another, perhaps more important, point is the bedding of the end of the set-screw upon the spindle. It is quite a common thing for both the end of the set-screw and the flat on the shaft

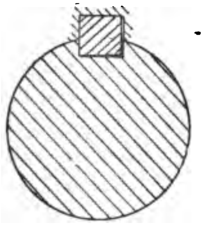
FIG. 101.

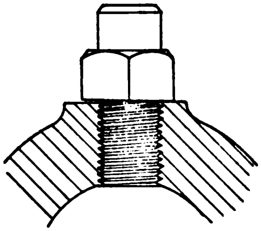
FIG. 102.

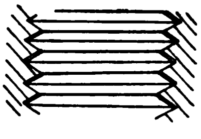
FIG. 103.

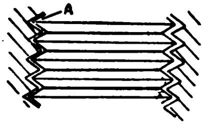

FIG. 104.

to be high in the centre as in Fig. 105. The result is that there is little more than the friction between the point of the set-screw and the spindle to prevent the lever twisting on the shaft. This is quite insufficient to hold satisfactorily a Corliss valve spindle lever. As soon as the slightest movement between the lever and the valve spindle takes place, the hammering action set up does the rest. The set-screw end should have a good broad surface, and if anything it should be a little hollow in the centre.

Referring to Fig. 106, supposing that there is a tendency for the spindle to twist round in the lever in the direction of the arrow, this tendency would first be met by the resistance to compression of the outside edge of the set-screw end at A. Now, it is obvious that if the end of the set-screw and the surface of the spindle whereon it beds are as in Fig. 105, the tendency to twist is met at a point very much nearer to the axis of the set-screw, and the corresponding resistance is much reduced. Another point that arises in this design is the difficulty of drilling and tapping a hole in the lever so that the centre line of the set-screw passes through the axis of the spindle. Should this error exist, the position of the flat on the valve spindle must be altered.

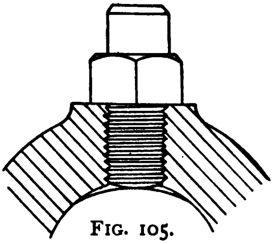

FIG. 105.

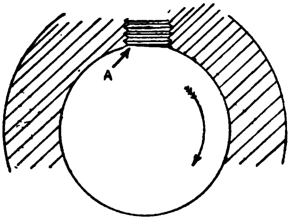

FIG. 106.

In Fig. 107, in which is shown, to an exaggerated degree for the sake of clearness, the axis of the set-screw diverging from that of the spindle, it will be noted that by tightening down the screw the spindle will be made to revolve in the direction of the arrow. Thus, to regain the original setting it will be necessary to file down the corner of the flat on the spindle at P. A worse state of affairs exists if the surface of the end of the set-screw is not exactly at right angles to the axis of the set-screw. This error is shown in Fig. 108, the high side of the set-screw being marked K, K in plan. Now, whether the set-screw will bed all over its end surface on the spindle depends upon the side where the thread in the hole commences. The best that can be hoped for is that the set-screw will just come down on to the spindle, when it is possible for the latter to twist round as shown in Fig. 109. Should it be necessary to tighten the set-screws any further, a little consideration will show that the points of the set-screws K, K, Fig. 109, only will rest upon the spindle. Of course the chances are very remote

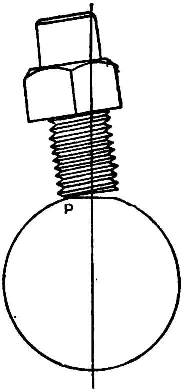

FIG. 107.

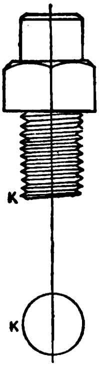

FIG. 108.

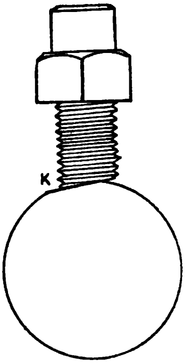

FIG. 109.

that the threads will be so cut as to produce the comparatively favourable conditions illustrated in Fig. 109.

Fig. 110 shows another view of the spindle and the conditions which will probably obtain when the end of the set-screw is not at right angles with the axis of the set-screw. It will be seen that the point K only of the set-screw is in contact with the flat on the spindle. Not only is the resistance to any movement of the lever on the spindle very small, but the set-screw will undoubtedly work slack. It will thus be seen that everything depends upon the most careful workmanship, and that, generally considered, the whole arrangement is undesirable. The errors illustrated are, of course, greatly exaggerated for the sake of clearness, but if surfaces which should be in contact are only a few thousandths of an inch apart, they are fulfilling their object as little as if there were inches of space between them. Furthermore, any movement of the lever round the spindle may lead to serious breakdown. Such an accident recently occurred in a horizontal Corliss engine driving a large spinning mill. The engine started knocking in an unaccountable manner on the L.P. side shortly after starting up in the afternoon. The knock, which could not be located, became so serious that the engine was shut down and the makers telephoned to send an expert along. The makers' engineer, on asking for an indicator diagram, was shown a card which had been taken at the commencement of the trouble, and saw that the compression curve ran right up off the paper. This pointed to a wrong setting of the exhaust valve, and upon further investigation it was found that through faulty workmanship in the fitting of the set-screw the lever on one exhaust valve spindle had shifted, with the result that the compression suddenly rose to an enormous figure. The piston was fastened on the rod by a cotter, and this had become flattened on its edges and bent, and the piston was knocking about on the rod.

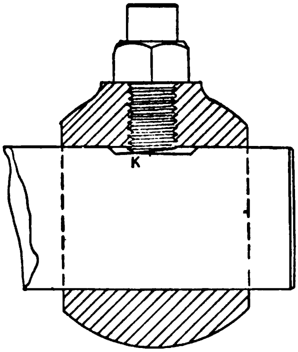

FIG. 110.

Stuffing-boxes with soft packing on Corliss valve spindles are not now regarded as the best practice. Not only are they a source of trouble and expense to keep tight, but the friction of such stuffing-boxes may, due to careless adjustment, rise to a very high figure. Soft packing also cuts and scores the spindles. A very satisfactory method is to replace the stuffing-boxes with a long brass bush, and still to make use of the bush in the outer end of the bridle as in Fig. 111. In order to prevent the escape of steam, the end of the bush A is turned to receive a spherical-sided washer, the other side of the washer being faced to bed up against a shoulder on the spindle. In order to make a good joint both sides of this washer should be ground down to a satisfactory bed. Now, supposing that this washer were made a good fit on the spindle, it would have one of two effects. Either the spherical side of the washer would be forced away from the bush when the spindle wore down, as in Fig. 112, or else the spherical form of the end of the bush would be destroyed by its becoming oval. In either case an escape of steam would take place. The erector should make sure that the hole in the washer is large enough to allow the spindle to drop sufficiently to allow for a reasonable amount of wear in the bush.

The above method of maintaining a steam-tight joint round the spindle is satisfactory as long as the pressure in the cylinder is greater than that of the atmosphere, since it is the pressure of the steam that holds the washer against the bridle. In the low-pressure cylinders the steam pressure will fall below that of the atmosphere, and another method must be found for keeping the washer on its seat. This is sometimes done by fitting a compression spring against the end of the valve spindle in the back cover. In other cases a couple of nuts are fitted on the valve spindle outside the cylinder, so that by them the spherical washer can be held and adjusted up to its seat should any wear take place.

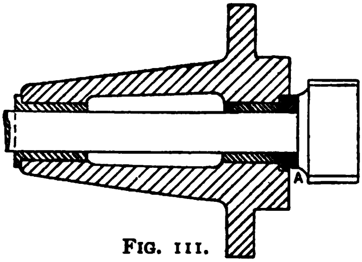

FIG. 111.

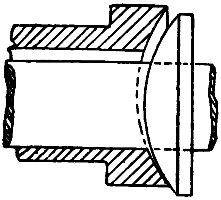

FIG. 112.

The main point deserving of attention in the erection of the various rods about a Corliss valve gear is to see that they point dead true—that is to say, that when the rod is coupled on to one pin it should swing directly on to the pin to which the other pin is to be attached. This condition should be obtained with the rod swung from each pin alternatively. Should this result not be obtained in the first instance, the brasses must be scraped on one side until the desired result is attained. One of the best rod ends is that illustrated in Fig. 113, A being a wedge block through which is screwed the pin B. By turning the screw either to the right or the left, the wedge block is alternatively raised or lowered, and when the correct adjustment has been obtained the set-screw is locked in position by means of the lock-nuts C. The upward movement of the wedge block obviously closes the brasses on to the pin, and a point worth noting is that the act of locking the set-screw by stretching the latter and forcing it down to the under side of its head tends to open the brasses. Therefore, in letting up the brasses they may be put more tightly up against the pin than will be actually required in the final adjustment. It will also be seen that with both ends of the rod similarly designed the centres of the rod tend to lengthen as adjustment for wear is made.

As in many other details in engine work, the results in the mind of the designer can be obtained only by careful and accurate workmanship. For instance, the design of the rod-end provides that the working thrust is transmitted to the rod through the surface of the back of the wedge block. Thus, unless this block is pressed hard against the rod at the time that the hole for the set-screw is drilled and tapped, there is a danger that this thrust will be taken by the set-screw, for which purpose it has not been designed. Another point of perhaps equal importance is that the axis of the set-screw must be exactly parallel with the surface X Y on the rod. Suppose that the hole for the set-screw has been drilled out of truth as shown to a greatly-exaggerated degree in Fig. 114, it is evident that as the set-screw is turned round and the wedge block raised, the set-screw will probably be distorted and bent by the working stress coming upon it. On the other hand, should the inclination of the set-screw be in the opposite direction, considerable force will be required to raise the wedge block, and the erector will be unable to tell by feel when the brass is up against the pin, since the block will be wedged between the set-screw and the rod. The taper surface of the wedge block where it is in contact with the brass must be true and square, otherwise, as the block rises, full contact will not be maintained. It appears to be the exception rather than the rule to find the eccentric rods quite linable when coupled up. It is probably due to this that eccentrics so frequently give trouble by heating. The eccentric straps are generally fitted with quite a little play between themselves and the sheave, and this leaves room for liberties to be taken with the alignment of the rod. Unless the rod is exactly linable, the strap cannot bear fully across the full width of the periphery of the sheave, and heating is bound to occur.

Scrupulous care should be taken to see that the dashpot is perfectly clean and free from grit before placing the plunger in position; and the same remark applies to the air passages and valves. Neglect of this precaution has caused many a dashpot to be scored and cut.

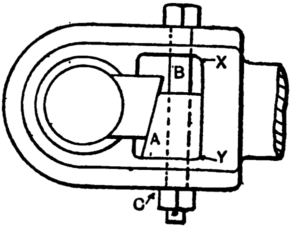

FIG. 113.

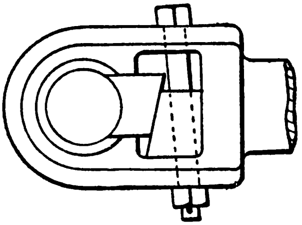

FIG. 114.

In setting a trip-gear it is arranged that the catches overrun one another by a certain amount which is known as the "clearance." This clearance is allowed to ensure that the catches engage fairly, and in general the amount of clearance allowed is about $\frac{3}{32}$in. Now, if the same amount of clearance is provided at both the front and the back of the cylinder, trouble may result with engines of a certain design. In tandem-cylinder engines there will be a considerable difference in the distance of the back end of the high-pressure cylinder from the crankshaft when the engine is running from what it will be after the engine has been standing for some time when the steam is shut off. This is due to the expansion of the cylinders under the influence of the high temperature of the steam. Now, as the valve-rods are surrounded by the air of the engine house, their expansion is negligible compared with that of the cylinders. If the clearance between the catches is arranged with the engine cold it is possible that as soon as the engine warms up the catches at the back end of the cylinder farthest from the crank will fail to engage. Similarly, if the clearance is adjusted finely whilst the engine is running, the same trouble may be met with at the front end of the cylinder when starting up. Other points in connection with valve-gears have been raised when dealing with high-speed engines earlier in this book, and they apply equally to the type of engine at present under consideration.

CHAPTER XXIII

OUTSIDE ERECTION

WHEN the erector is selected from among the workmen in the shops to erect and start up an engine outside, he enters upon the status of an engineer. Men of exceptional intelligence and ability have waited for years for an opportunity to show their worth, until their chance has come by their being sent to erect a job outside. An erector so chosen becomes automatically a duly qualified representative of his firm in many matters, and upon his tact and judgment a good deal of the interests of his firm may depend. A workman in the shop may be only a unit, whereas outside he has the attention of the management focused upon him. The first job outside may be an important step in the advancement of a career, and yet it may be stated that not one in ten good workmen in the shops rise to the occasion when sent to work outside. This is partly due to the fact that the man cannot stand the freedom from restraint and from the discipline to which he has become accustomed in the works. Having been used to have at his elbow a superior official to whom he can refer the slightest difficulty that may arise, he lacks that self-confidence which will enable him to come to a decision on his own responsibility.

Every job is comparatively smooth and straightforward in the works, whereas outside difficulties are the rule and straightforward jobs the exception. The outside charge-hand is subject to temptations which are absent when working in the shops. For instance, his timekeeping is not often as rigidly watched, and if a few minutes late in the morning he is inclined to book his time from the proper starting hour. This is a habit that easily grows upon one, and the minutes cribbed may soon become hours, and the practice may end in disaster.

In cases where a man's timekeeping depends upon his honour it is impossible to be too rigid, even from a purely business point of view. The same applies to the handling of petty cash belonging to the firm. Many sad cases of ruined careers have been due to a little carelessness and plausibility in the first instance. An outside erector who intends to get on must be, like Cæsar's wife, above even suspicion.

One of the more important qualifications in an outside erector is the ability to write a clear and intelligible report. It is necessary for the management to know exactly how each job stands, but when the reports from the outside jobs come in some are found to be almost illegible and incoherent, whilst a few are a pleasure to read. The shorter a report is the better, provided that it contains the desired information. In some cases the art of report writing appears to be a gift, but it can always be acquired by care and practice. A good plan for the young erector sent out for the first time is first to write out a synopsis of the points he wishes to dwell upon in their proper order, and then to draft out a preliminary report, which, after carefully reading through, he will correct and finally carefully copy out and dispatch to his firm. It is sometimes a great temptation, where the erector is pressed for time, to write a report with dirty hands. This is a mistake, since, apart from the subsequent difficulty in deciphering it, such a report gives the impression that the writer is slovenly, and will probably be as slipshod in his work as he is in making his reports. A copy of each report should always be retained, and similarly all letters from his firm should be preserved. Unless this is done the erector will have only his memory to rely upon in case of any dispute arising as to what and when he wrote.

There is a saying among outside erectors to the effect that the next best thing to doing a good day's work is to write a slashing report finding fault with either the drawings or with the material sent out, but this practice can easily be carried too far. It is often in the interests of a firm that faults and mistakes should be respectfully pointed out, but to dwell too gloatingly upon them, and to magnify unduly petty faults, not only create bad blood unnecessarily, but also give the impression that the writer is a greater critic than a workman. Reports should be sent in at certain definite intervals so that the management will always know when to expect them—that is, of course, supposing that some urgent matter does not crop up that must be dealt with immediately.

When an erector has been told to hold himself in readiness to go and erect a job outside, he should see that he has a complete set of erection prints, and should make himself quite conversant with what work has to be done by his own firm, what work is to be carried out by the purchasers, and also what portion of the work has been put, or is to be put, into the hands of sub-contractors to his own firm. He should also obtain, if possible, a complete specification of the job, as this will not only save unnecessary correspondence but will prevent delay or overlapping of the work. A case recently occurred where one firm supplied the 15in. steam mains as far as the engine stop-valve, the engine being supplied by a separate manufacturer. The representatives of both firms refused to supply the bolts, which were specified to be of a carbon steel, and the engine could not be started up until each had referred the matter to headquarters and some further correspondence had taken place between the head offices.

Some firms make a point of sending out from their own works to every job all lifting and other tackle required, while in other cases the tackle has to be obtained locally. The latter practice is frequently adopted where the engine has to be erected a long distance from the works. In such cases the cost of carriage from the works might be prohibitive for the heavier tackle. Where the tackle and tools are supplied from headquarters it often devolves upon the erector to select his own tackle, under the supervision of the outside manager. The erector will have to get a good idea of the weights to be handled, the heights of lift, and the headroom available. It is far better to overhaul the tackle before its leaving the works than to have to return it from the job, or be tempted to use tackle that is not quite safe or suitable. Ropes and chains should be carefully examined, and blocks hung up and worked to make sure that they are in good repair, and in safe and free working condition. When the safety of life and limb is involved, extra care in the examination of all tackle is imperative. In the writer's experience, hydraulic jacks as taken out of the stores generally require overhauling before they can be got to work, and if this has to be done on the job, the time spent would be booked against the outside erection, and to the discredit of the erector. It appears to be the common practice of the trade to test chain blocks only up to their nominal capacity—that is to say, a set of 2 ton chain blocks would be tested only up to 2 tons. If makers do not care to put more than their nominal load upon chain blocks when new, the erector would be well advised to keep well within the nominal load after they have been some time in use. The case is different with rope blocks. The condition of ropes can be ascertained from inspection; and while chain blocks have the advantage that they are self-sustaining, the erectors can do things with a pair of rope blocks where chain blocks could not be used. The former are lighter, easier to handle, and are almost indispensable for high lifts. Their use, however, requires a certain knowledge and practical experience of "rigging," which every erector should cultivate.

In some cases the material is on the job when the erector arrives; but more generally he has to be on the spot to take delivery of same, and this probably means that he will require tackle for unloading. The entrance to the engine-room through which the machinery has to pass is often constricted, and the floor space in the engine-house comparatively small. It is often the case that the engine-room will not contain at one time all the engine parts and at the same time leave clear the space on which the engine has to be erected. This means that the various parts will have to be delivered and received in a certain definite order. To enable this work to be carried out smoothly, the erector should go down to the railway goods yard and interview the stationmaster or local goods-traffic manager, and impress upon him the fact that by delivering the goods in the order and at the times specified, any delay of the railway company's horses and men on the job will be cut down to the lowest possible minimum, and if the goods are not delivered as arranged the erector's firm cannot be responsible for any probable delay involved. He should inspect the roadway leading to the engine-house, and from its form and general condition he should be able to advise the railway authorities as to the maximum load which should be put on to a lorry, and the number of horses required to haul it into the required position. With new buildings the roads are often soft and in bad condition, and there is often insufficient room for the lorry to turn. In such cases it may be necessary to use tackle to get the lorry in a suitable position for unloading; if so, the erector should look ahead and have his tackle ready. A good understanding having thus been promoted, the erector should be in constant touch with the railway company, and this can generally be done by means of the telephone. The erector, on his part, should remember that horses cannot always be provided at a moment's notice, and should endeavour to give the railway company at least 24 hours' notice when he wants the goods forward; and in cases where a special lorry is required more notice still is often required.

Detailed advice notes will be sent from the works giving a list of all parts included in each consignment, and unless the firm be advised to the contrary it will be justified in assuming that the erector has received all parts specified. Therefore the parts of each consignment should be carefully checked over against the advice note, and if the parts do not tally the firm should be immediately advised. If this checking over be left till the last moment the job may be seriously delayed for want of some missing part. In the same way, all goods received from the railway company should be signed for as "unexamined," and should be overhauled with as little delay as possible, so that should any breakage be discovered headquarters can be immediately advised, and the broken parts can be replaced, a claim at the same time being made against the railway company. A frequent source of trouble is the method of dealing with empty packing cases. As soon as these are empty they should be returned to the works, and an advice note of their dispatch forwarded, a dated duplicate being kept by the erector. It often happens that certain material required for an engine, instead of being sent from the works, is bought outside and sent direct from the makers. It is the practice of some firms to make use of exceedingly light packing cases, and to put an exorbitant price upon them, often many times their actual value. A really good thing is often made by this system. The erector, being forewarned, should open such cases with the utmost care, and when empty return them to the senders. Even if they fall to pieces when opened the parts should be similarly returned, sending to his own firm a duplicate of the advice note dispatched to the firm who supplied the case. Care in details such as the above saves a lot of vexatious correspondence and trouble in the secretary's office.

On a large job the erector will have under his charge a quantity of valuable tools, and it is a fact that when working outside it is not an easy matter to keep them in his possession. This is especially the case when several contractors have men on the job at the same time, since there seems to be a common idea abroad under these circumstances that "finding is keeping." Some erectors with a natural gift of acquisitiveness return to the works with a very much better kit of tools than they took out with them; but it usually happens that the contractor's men, who are the last to leave the job, return with the lightest tool-boxes. The first essential is a strong lock-up tool-box, of which the erector himself keeps the key, and all tools should be checked over and locked up every night. By cultivating friendly relations with other contractors' men a lot of useful tools and tackle can be borrowed; but unless these are scrupulously returned after use further applications are not likely to be met in an accommodating spirit. Not only should the erector look ahead on his own work, but he should give plenty of notice, either direct or through his firm, as to when he is likely to be ready for the sub-contractors to start upon their portion of the work. Cases in point are the fixing of metallic packings and the placing of non-conducting composition on the cylinders and steam pipes. Owing to the makers not being advised until the last minute more than one engine has been seriously delayed, and this could have been easily prevented by the exercise of a little forethought.

Finally, it is better to take a little longer over the erection of an engine and start up without a hitch than for the erector to injure his own reputation and that of his firm through undue haste.

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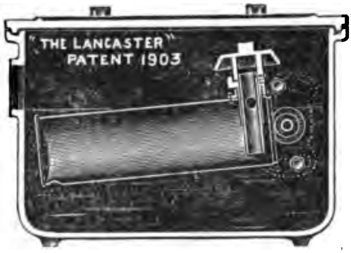

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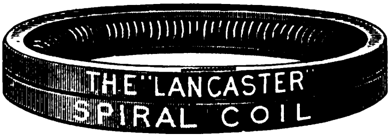

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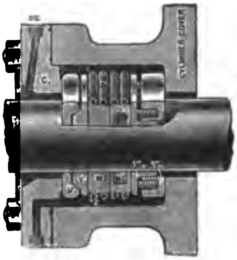

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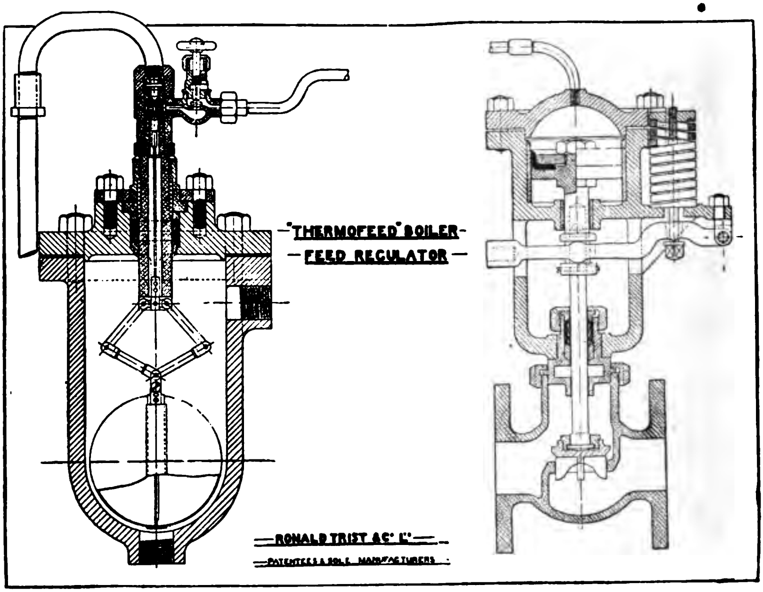

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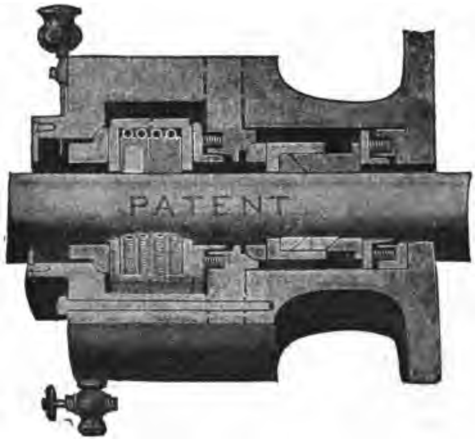

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